SOIL, WATER, AND AIR RESOURCES TRAINING COURSE

7000.1

USDI BUREAU OF LAND MANAGEMENT
Phoenix Training Center
Phoenix, Arizona
April 21 - May 2
1986

Preface

This is the first time that Training Course 7000.1, Soil, Water, and Air Resources Management, has been offered as part of the Bureau of Land Management Training Program. The course was conceived over four years ago to offer newly hired hydrologists and soil scientists a comprehensive introduction to the Bureau of Land Management and it's Soil, Water, and Air Resources Program. For a number of reasons the Course was never offered.

Over the past four years there have been several changes which influenced the design of Course 7000.1. First, there have been very few "new" hydrologists or soil scientists hired. Second, the emphasis of the Soil, Water, and Air Program has been evolving in response to changing issues, program objectives and policies, and technologies. Third, the time allocated for Course 7000.1 was reduced from six weeks to two weeks. Thus, instead of a comprehensive inroductory training course, the present course is intended to update practicing BLM soil scientists, hydrologists, soil conservationists, and other resource specialists with primary responsibilities in the soil and water programs on program policies, directions, issues, and analytical tools. Since many policies, issues, analytical tools, and areas of program emphasis are new, the course should be appropriate for resource specialists with any level of technical background or professional experience.

The course is divided into ten topic areas. However, several recurring themes serve to unite several of the topics. For example, program policies will be discussed formally, but also will be integral to subsequent discussions of issues, and the implementation of effective field office soil, water, and air programs. The planning system will be described formally, but aspects of the planning system, including watershed analyses, watershed activity planning, and monitoring will be the subject of subsequent field office presentations and hands-on exercises. Finally, there is the overriding theme that technical skills, communication skills, and professional behavior are key elements in effective job performance.

The BLM Soil, Water, and Air Resources Program is extremely diverse in terms of issues, program emphasis, and professional skills mixes at the field office level. As such, it is impossible to address all topics of interest to soil, water, and air resources specialists. Also, since most of the topics planned for this course could easily be the subjects of separate expanded training courses, there are practical limitations to the depth to which individual subjects can be covered. It has to be assumed, therefore, that once introduced to a subject area, and/or related professional contacts, the professional can take it upon himself to expand or advance his expertise as needed, or to pursue other topics not covered formally in this course. In this regard, it is hoped that one of the most useful aspects of this course will be the interaction facilitated between fellow soil, water, and air resource specialists throughout the Bureau of Land Management.

Preface

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SOIL, WATER, AND AIR RESOURCES TRAINING COURSE 7000.1

Course Coordinator	William L. Jackson, Denver Service Center, D-470
Training Coordinator	Gary Dreier, AZ-960 Cal McCluskey, AZ-960 Jacalyn Johnson, AZ-960
Washington Office Program Support:	James Stone, WO-222 Daniel Muller, WO-222 Stan Coloff, WO-222
Special Assistance:	Ronnie Clark, Denver Service Center, D-470
Special Acknowledgement:	Safford District Office

1986 Soil, Water, and Air
Training Course (7000.1)

Purpose

To update practicing BLM Soil Scientists, Hydrologists, Soil Conservationists, and other resource specialists with primary responsibilities in the soil and water programs on program policies, direction, issues, and analytical tools.

General Objectives

1. To be able to describe the SW program as outlined in the new draft 7000 Manual.

2. To be able to describe the budget process at all BLM organizational levels.

3. To be able to describe the philosophy and design of the Resource Management Planning System and the role of soil and water specialists in resource management planning, and activity planning.

4. To be able to describe and prepare components of a watershed analysis and a watershed activity plan.

5. To be able to describe the applications of GIS in planning, and to conduct a simple watershed analysis using a GIS.

6. To be able to use personal computers in hydrologic design, watershed modelling, data storage, and statistical analyses.

7. To be able to describe the components of a watershed monitoring plan and common watershed monitoring approaches, and to apply common sampling designs and data analysis methods.

8. To be able to describe important soil and water issues, the role of soil and water specialists, and responsibilities for addressing those issues.

9 To be able to describe program responsibilities in air resources management.

10. To identify deficiencies in individual soil and water programs, manager-specialist communications, and professional behavior, and develop strategies for improving both personal and program effectiveness.

AGENDA
1986 Soil, Water, and Air Training Course (7000-1)

DATE	TOPIC	INSTRUCTOR
Mon. 4/21	- Course Objectives, Organization	Jackson (D-470)
	- Soil/Water Program: Goals, Objectives, Policies	Stone (WO-222)
	- Budget Process	D. Muller (WO-222)
	- Resource Management Planning: Soil/Water Role	K. Muller (WO-202)
Tues. 4/22	- Watershed Condition Analysis	Stone (WO-222)
	- Watershed Activity Planning (Overview)	D. Muller (WO-222)
	- Watershed Activity Planning (Field Implementation)	Hooper (Cedar City)
	- Development/Use of Soil Interpretations	Volk (MT-932)
Wed. 4/23	- GIS in Resource Management Planning	Foster (D-443) Webster (TGS)
	- GIS: Hands-on Exercises	
Thurs. 4/24	- Using Personal Computers	Gebhardt (ID-932)
	- Personal Computer Lab. (Design hydrology, forage production, soil data bases, runoff and sediment modelling)	Gebhardt (ID-932) Jackson (D-470)
Fri. 4/25	- Field Trip: San Simon Project (Class will travel to Safford Thursday evening.)	McGlothlin (AZ-932) Safford DO
Sat. 4/26	- Field Activity Planning Exercise (Class will return to Phoenix Saturday Afternoon.)	Van Haveren (D-470) Humphreys (Safford DO)
Mon. 4/28	- Watershed Analysis/Activity Planning Exercise	Van Haveren (D-470)

Tues. 4/29	-	Soil/Water Monitoring Concepts	Jackson (D-470)
	-	Study Designs Computer Lab: Data Analysis, Statistical Tests	Hudson (D-470)
Wed. 4/30	-	Soil/Water Issues (Water Rights, Hazardous Waste, Dam Safety, Salinity Control, Energy EA's	D. Muller (WO-222) Vandas (CO-932)
		Riparian Area Management	D. Muller (WO-222) Jackson (D-470) Murphy (Montrose DO)
Thurs. 5/1	-	Air Resource Activities	Archer (CO-932), Wagner (UT-932)
	-	Managers' Perceptions of Soil/Water/Air Programs panel discussion	Huff (CSO)
Fri. 5/2	-	Closeout and Evaluation	
		(Adjourn at Noon)	

COURSE TITLE SOIL, WATER, AND AIR MANAGEMENT COURSE NUMBER 7000-1

SCHED LE FOR WEEK OF APRIL 21-26, 1986 WEEK NUMBER 1

MONDAY April 21	TUESDAY April 22	WEDNESDAY April 23	THURSDAY April 24	FRIDAY April 25
Convene 8 a.m.	Convene 8 a.m.	Convene 8 a.m.	Convene 8 a.m.	Convene 8 a.m.
Welcome & Introductions	Watershed Condition Analysis Jim Stone	GIS-Resource Management John Foster, D-443	Using Personal Computers Karl Gebhardt, ID-932	Field Trip: San Simon Project Dan McGlothlin, AZ-930
Soil/Water Program Goals, Objectives, Policies Jim Stone, WO-222				
	Watershed Activity Planning Dan Muller			
Budget Process Dan Muller, WO-222	Watershed Activity Planning (Field Impl.) Ron Hooper, Cedar City, UT		Personal Computer Lab. Karl Gebhardt Bill Jackson, D-471	
LUNCH BREAK 11:30 - 12:30				
Resource Management Planning: Soil/Water Role Kit Muller, WO-202	Development/Use of Soil Interpretations Bill Volk, MT-932	GIS-Exercises		
			Leave for Safford	April 26 - Saturday Continue Field Exercise
				Return to Phoenix
Adjourn 4 p.m.	Adjourn 4 p.m.	Adjourn 4 p.m.	Adjourn 4 p.m.	

POLICY

SOIL AND WATER PROGRAMS

Course Objectives: Upon completion of this segment, students should be able to:

1. List and describe the function of the different elements in the Bureau Directives System;

2. Prepare a one-page summary describing the Soil and Water Programs and justifying their existence to a new Bureau employee;

3. List the major steps in the budget process and explain how you (in your present position) can facilitate budget preparation.

Topic Outline

I. Historical Perspective (How did we get where we are?)

- A. Soil and Moisture - the 60's
- B. Watershed Conservation and Development - the 70's
- C. Soil, Water, and Air Management - the 80's

II. Program Direction and Guidance (Where are we, anyhow?)

- A. Building From a Logical Base
- B. Program Objectives and Policies
- C. Manuals/Handbooks/Technical References - Status

III. Programming and Budgeting (Where have all the dollars gone?)

- A. Budget Process - How it is supposed to work
- B. Budget Process - How it does work
- C. Your Role in Programming and Budgeting

JAMES E. STONE
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CAREER EXPERIENCE

1985 - Present	Soil Scientist, BLM, Div. Rangeland Resources, Wash. D.C.
1980 - 1985	Soil Scientist, BLM, Div. Resource Systems, Denver Service Center
1977 - 1980	Soil Conservationist, BLM, Div. Resources, Montrose, CO
1976 - 1977	Soil Scientist, BLM, Soil Survey Party, Socorro, NM
1974 - 1976	Research Faculty, Dept. Agronomy, Cornell University
1969 - 1974	Research Assistant, Dept. Natural Resources, Cornell Univ.
1967 - 1969	Research Assistant, Water Resources Research Institute, Laramie, WY
1966 - 1967	Teaching Assistant, Dept. Biology, Hamline Univ.

EDUCATION

PhD, Terrestrial Ecology, 1974, Cornell Univ., Ithaca, NY

MS, Botany, 1969, Univ. Wyoming, Laramie, WY

BS, Biology, 1967, Hamline Univ., St. Paul, MN

OTHER INTERESTS

Woodworking, carpentry, gardening

AGENDA

SOIL, WATER, AIR OBJECTIVES

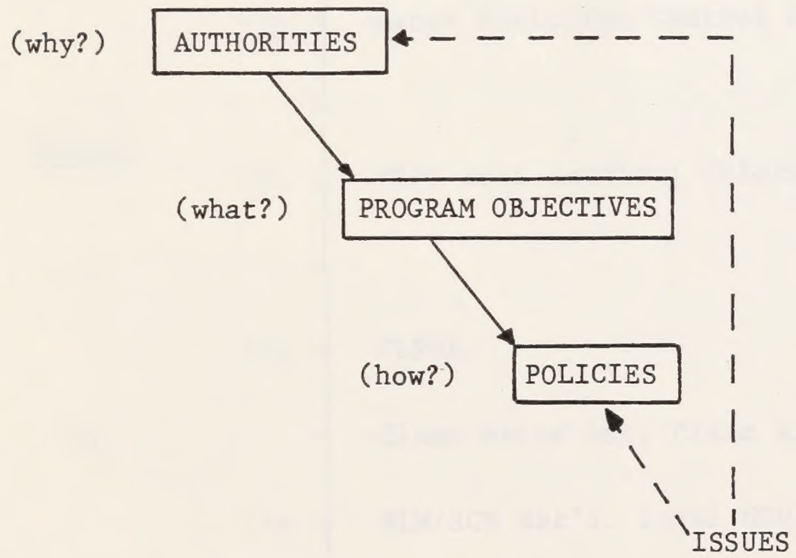
A. PREVENT IMPAIRMENT OF SOIL PRODUCTIVITY DUE TO ACCELERATED SOIL LOSS OR PHYSICAL OR CHEMICAL DEGREDATION OF THE SOIL RESOURCE.

B. ENSURE THE BUREAU MANAGMENT ACTIONS AND OBJECTIVES ARE CONSISTENT WITH SOIL RESOURCE CAPABILITIES.

C. MAINTAIN OR IMPROVE SURFACE AND GROUND WATER QUALITY CONSISTENT WITH EXISTING AND ANTICIPATED USES AND APPLICABLE STATE AND FEDERAL WATER QUALITY STANDARDS.

D. MINIMIZE THE HARMFUL CONSEQUENCES OF UNCONTROLLED WATER FLOWS ON OR ARISING FROM BUREAU-ADMINISTERED LANDS.

E. PROVIDE FOR THE PHYSICAL AND LEGAL AVAILABILITY OF WATER TO FACILITATE AUTHORIZED USES OF THE PUBLIC LANDS.



PERSONNEL: Soil Sci.	Hydrol.		EVENTS
		1930	
			Taylor Grazing Act (1934); Soil Conservation and Domestic Allotment Act (1935); O & C Act (1937)
		1940	
		'46	BLM established from Grazing Service & Gen. Land Office
		1950	
			Halogeton Control Act
		'54	Watershed Protection & Flood Control Act (PL 566)
			Secretarial Order - Soil & Moist. functions delegat. to BLM
		1960	
			Vale Project *et al.* funded
		'64	Classification and Multiple Use Act; 1st policy on soil survey
			National Environmental Policy Act (NEPA)
		1970	WO Div. Watershed established; Clean Air amendments
		'72	Water Pollution Control Act (PL 92-500)
		'74	NRDC suit settled; Colorado Salinity Act
40			
		'76	FLPMA
	23		Clean Water Act; Clean Air amendments; Floodplian Mgmt. EO
		'78	BLM/SCS Nat'l. level MOU on soil survey; PRIA
100			WO Div. Watershed abolished; water policy staff estab.
122	81	1980	1st Soil Sci. and Hydrol. hired into Div. Rangeland
115	76		
103	75	'82	Water Policy Staff abolished (dissolved?)
93	69		
83	62	'84	Branch of Soil, Water, Air (222) created
74	60		4340 split into 4341 & 4342

4/4/85

7000 SOIL, WATER, AND AIR RESOURCES

7100 SOIL RESOURCE

.1 Soil Resource Program
.2 Soil Survey Operations
.3 Soil Classification and Mapping
.4 Soil Survey Reports
.5 Soil Interpretations
.6 Site-Specific Evaluations
.7 Soil Information Systems

7200 WATER RESOURCES

7210 Watershed Condition Analysis

7220 Watershed Activity Planning

7230 Groundwater

7240 Water Quality

7250 Water Rights

7260 Floodplains

7300 AIR RESOURCE

.1 Air Resource Program
.2 Air Resource Management Activities
.3 Air Resource Inventory
.4 Air Resource Monitoring
.5 Air Resource Modeling
.6 Air Resource Training and Education

Guidance System

Legislation, Executive Orders, and Court Orders: Taylor Act, FLPMA, PRIA, etc.

Grazing Regulations: 43 CFR 4100 (Oriented Toward the Public)

Departmental Manuals: (are typically general instructions)

BLM Directives

Long Term Directives (Manual System)

Manual Sections: Policy, and Standards (Written for Managers)	Manual Handbooks: Required Procedure and Standards (detailed); written for Staff/Technical personnel	Reference System: Optional Procedure and Technical Information
1622 - Supplemental Program Guidance for Renewable Resources Programs (WO IM 86-136)		
4100 - Grazing Administration (Excl. of Alaska) (Rel. 4-69, 6/20/84)		
4110 - Qualifications and Preference (Rel. 4-70, 6/20/84)	H-4110-1 - Qualifications and Preference (Rel. 4-71, 6/20/84)	
4120 - Grazing Management (Rel. 4-72, 6/20/84)	H-4120-1 - Grazing Management (Rel. 4-73, 6/20/84)	
4130 - Authorizing Grazing Use (Rel. 4-74, 7/2/84)	H-4130-1 - Authorizing Grazing Use (Rel. 4-75, 7/3/84)	
4150 - Unauthorized Grazing Use (Rel. 4-76, 5/16/84)	H-4150-1 - Unauthorized Grazing Use (Rel. 4-77, 7/3/84)	
4160 - Administrative Remedies (Rel. 4-78, 6/20/84)	H-4160-1 - Administrative Remedies (Rel. 4-79, 7/3/84)	
4400 - Rangeland Inventory, Monitoring, and Evaluation (Rel. 4-64, 12/1/83)		TR-4400-1 - Rangeland Monitoring: Planning for Monitoring (p-205)
4410 - Ecological Site Inventory (Rel. 4-80, 7/12/84)	H-4410-1 - National Range Handbook (Rel. 4-81, 7/12/84)	TR-4400-2 - Rangeland Monitoring: Actual Use Studies (p-206) TR-4400-3 - Rangeland Monitoring: Utilization Studies (p-207) TR-4400-4 - Rangeland Monitoring: Trend Studies (p-208) TR-4400-7 - Rangeland Monitoring: Analysis, Interpretation, and Evaluation (p-209)
1740 - Renewable Resource Improvements and Treatments (Rels. 1-1427 and 1-1417) 6/28/85 and 9/3/85	H-1740-1 - Renewable Resource Improvement and Treatment Procedures; draft now being revised	
1741 - Renewable Resource Improvements, Practices, and Standards (Rel. 1-1418, 4/11/85)	H-1741-1 - Fencing (Rel. 1-1419, 5/20/85)	R-1741-1 - Revegtation Equipment Catalog (p-229)
1742 - Emergency Fire Rehabilitation (Rel. 1-1423, 8/8/85)	H-1742-1 - Emergency Fire Rehabilitation (Rel. 1-1424, 8/8/85)	
1743 - Renewable Resource Investment Analysis (Rel. 1-1429, 4/11/85)	H-1743-1 - Resource Investment Analysis User Handbook for the SageRam Computer Program (Rel. 1-1430, 9/9/85)	
		T/N 337 - Hydrologic Risk and Return Period for Water Related Projects
7000 - Soil, Water, and Air Management (Rel. 7-85, 3/8/84)		T/N 366 - Gully Erosion
7100 - Soil Resource Management (Rel. 7-87, 8/15/84)		T/N 369 - Considerations in Rangeland Watershed Monitoring
7221 - Floodplain Management (Rel. 7-66, 2/14/79)		T/N 368 - A Runoff and Soil-Loss Monitoring Technique Using Paired Plots TR 4341-1 - Channel Cross Section Surveys and Data Analysis
7240 - Water Quality (Rel. 7-63. 3/19/84)		TR 7230-1 - Guidelines for Conducting Groundwater Studies in Support of Resource Activities
7250 - Water Rights (Rel. 7-86, 3/19/84)		T/N 369 - 1980-82 Salinty Status Report Hydrologic Design and Analysis Programs T/N 370 - Predictive Model for Estimating Maximum Summer Stream Temperatures in Western Oregon Reynolds Creek Summary Report Instream Flow Guidelines - BLM

Short Term Directives: Instruction and Information Memos

7000 - SOIL, WATER, AND AIR MANAGEMENT

Table of Contents

7000 - SOIL, WATER, AND AIR MANAGEMENT

.01 Purpose. This Manual Section provides policy and guidance for the management of soil, water, and air resources and watershed values associated with lands administered by the Bureau of Land Management (BLM).

.02 Objectives.

A. To protect, maintain, or improve the quality of the soil, water, and air resources and watershed values associated with the public lands, including natural site productivity; air quality; and surface and ground water quality, quantity, and timing.

B. To prevent deterioration of soil, air quality, and watershed conditions where technically and economically feasible and to rehabilitate areas where accelerated erosion and runoff have resulted in unacceptable resource conditions.

C. To prevent or minimize the threat to public health and safety, damages to natural site characteristics, or economic losses due to: floods, sedimentation, decreased water and air quality, or accelerated runoff and erosion.

.03 Authority. The Soil, Water, and Air Management Program is conducted under the following authorities:

A. Statutes.

1. Economy Act of 1932, as amended, P.L. 72-211, 44 Stat. 417, 31 U.S.C. 686, June 30, 1932. This Act authorizes reimbursable transfers of materials and services between Federal agencies. The Act forms the basis for agreements between the BLM and the Soil Conservation Service (SCS) concerning soil survey work; between the BLM and the Geological Survey (GS) for certain stream monitoring activities; and between the BLM and the GS, the Forest Service, the National Park Service, and the Environmental Protection Agency for air resource monitoring and impact modeling activities.

2. Taylor Grazing Act of 1934, as amended, P.L. 73-482, 48 Stat. 1269, 43 U.S.C. 315, June 28, 1934. This Act provides for the orderly use, improvement, and development of the range; the regulation of occupancy and use to preserve the land and its resources from destruction or unnecessary injury; for continued study of erosion and flood control; and for any such work as may be necessary to protect and rehabilitate the public lands in order to prevent soil deterioration.

3. Soil Conservation and Domestic Allotment Act of 1935, as amended, P.L. 74-46, 49 Stat. 163, 16 U.S.C. 590, April 27, 1935. By Reorganization Plan No. IV and Secretary Order 2835, this Act authorizes the BLM to conduct and publish surveys, investigations, and research relating to the character of soil erosion; to disseminate information on erosion prevention measures; and to conduct demonstration projects in areas subject to wind and water erosion. The Act further provides for the "preservation and improvement of soil fertility, promotion of the economic use and conservation of land, and diminution of exploitation and wasteful and unscientific use of national soil resources."

4. Revested Oregon and California Railroad and Reconveyed Coos Bay Wagon Road Grant Lands Act of 1937, as amended, P.L. 75-405, 50 Stat. 874, 43 U.S.C. 1181, August 28, 1937. This Act provides for management of the revested Oregon and California Railroad lands and the reconveyed Coos Bay Wagon Road lands to provide a permanent timber supply under the principle of sustained yield, as well as to protect watersheds and regulate streamflow.

5. Appropriations Act of 1952, McCarran Amendment, 66 Stat. 56, 43 U.S.C. 666, July 10, 1952. This amendment allows the United States to be joined as a defendant in any suit for the general adjudication of water rights.

6. Watershed Protection and Flood Control Act of 1954, as amended, P.L. 83-566, 68 Stat. 666, 16 U.S.C. 1001 et seq., August 4, 1954. Under this Act, the Federal Government is directed to cooperate with States and their political subdivisions, soil or water conservation districts, flood prevention or control districts, and other local public agencies to prevent erosion or floodwater and sediment damage.

7. Water Resources Research Act of 1954, as amended, P.L. 88-379, 78 Stat. 329, 42 U.S.C. 1961, July 17, 1964. Under this Act, the Secretary of the Interior may give grants to, and cooperate with, Federal, State, and local agencies to undertake research into any water problems related to the mission of the Department.

8. Water Resources Planning Act of 1965, as amended, P.L. 89-80, 79 Stat. 244, 42 U.S.C. 1962 et seq., July 22, 1965. This Act establishes the Water Resources Council, which is directed to maintain studies of water supplies and water programs. The Chairman of any River Basin Commission can request from an agency, and that agency is authorized to furnish, such information necessary to carry out its functions.

9. Soil Information Assistance for Community Planning and Resource Development Act of 1966, P.L. 89-560, 80 Stat. 706, 42 U.S.C. 3271 et seq., September 7, 1966. This Act directs the Secretary of Agriculture to provide assistance to States and other public agencies in the classification and interpretation of kinds of soil and in the intensification of use and benefits of the National Cooperative Soil Survey. The Act further provides for consultation with other Federal agencies to assure coordination of work.

10. National Environmental Policy Act (NEPA) of 1969, as amended, P.L. 91-190, 83 Stat. 852, 42 U.S.C. 4321 et seq., January 1, 1970. This Act requires that agencies prepare environmental impact statements for Federal actions expected to "significantly affect the quality of the human environment." In addition, agencies are required to use a systematic, interdisciplinary approach in planning and decisionmaking processes that will affect the environment.

11. Clean Air Amendments of 1970, P.L. 91-604, 84 Stat. 1676, 42 U.S.C. 1857 et seq., December 31, 1970. These amendments to the Clean Air Act of 1955, authorize the establishment of National Ambient Air Quality Standards for major pollutants. Meeting these standards is primarily a State responsibility and is to be accomplished under individual State Implementation Plans. The Bureau must comply with national and State air quality standards and is directed to cooperate with the States in carrying out their implementation plans.

12. Water Resources Development Act of 1974, P.L. 93-251, March 7, 1974. Directs agencies to consider the full range of potentially useful measures in all projects involving reduction of flood losses.

13. Colorado River Basin Salinity Control Act of 1974, P.L. 93-320, 88 Stat. 266, 43 U.S.C. 1571 et seq., June 24, 1974. This Act directs the Department of the Interior to undertake research and develop demonstration projects to identify methods to improve the water quality of the Colorado River.

14. Federal Land Policy and Management Act of 1976, as amended, P.L. 94-579, 90 Stat. 2743, 43 U.S.C. 1701 et seq., October 21, 1976. This Act provides for management of the public lands under principles of multiple use and sustained yield. The Act specifically calls for the periodic and systematic inventory of public land resources; the development, maintenance, and revision of land-use plans using an interdisciplinary approach; and compliance with State and Federal air and water pollution standards. The Act further directs the Secretary of the Interior to take any action necessary to prevent "unnecessary or undue degradation of the lands."

15. Clean Air Act Amendments of 1977, P.L. 95-95, 91 Stat. 685, 42 U.S.C. 7401 et seq., August 7, 1977. This Act revises the Clean Air Act of 1970, as previously amended. The Act provides for the "prevention of significant deterioration" of air quality and places significant responsibility upon the Federal land manager for protection and, in certain cases, for enhancement of air quality and air quality related values including visibility.

16. Safe Drinking Water Amendments of 1977, amended Section 2 of the Safe Drinking Water Act, P.L. 95-190, 42 U.S.C. 201, November 16, 1977. These amendments require the BLM to be in compliance with all Federal, State, or local statutes for safe drinking water. The BLM campgrounds and recreation site water supply systems are affected.

17. Clean Water Act of 1977, as amended, P.L. 95-217, 33 U.S.C. 404, December 27, 1977. This Act requires the BLM to participate with State and Federal Governments in water quality planning and permitting activities. It requires exchanging data, resource planning, revising standards, and developing best management practices for the control of nonpoint source pollution. In many States, the BLM has been appointed the designated management agency responsible for control of nonpoint pollution on public lands.

18. Public Rangelands Improvement Act of 1978, P.L. 95-514, 92 Stat. 1803, 43 U.S.C. 1901 et seq., October 25, 1978. This Act establishes and reaffirms a policy to maintain an inventory of range conditions and trends and to manage for improvement of the public rangelands so that they become as productive as feasible. The Act establishes a national policy to inventory and identify current public rangelands' soil and water conditions and trends and to manage, maintain, and improve the condition of these lands. Range improvement is defined to include providing water, stabilizing soil and water conditions, and providing habitat for wildlife. The Act also requires monitoring to reflect changes in soil and water conditions over time.

19. Classification and Multiple-Use Act (78 Stat. 986, 43 U.S.C. 1411-18), 43 CFR 1725.3-3(h) as of October 1, 1981. One of the 10 objectives of public land management listed in the Act is "Watershed Protection," which is defined as the protection, regulated use, and development of any public lands in a manner to control runoff; to minimize soil erosion, siltation, and other destructive consequences of uncontrolled water flows; and to maintain and improve storage, yield, quality, and quantity of surface and subsurface waters.

20. Farmland Protection Policy Act, Title XV, Subtitle I of P.L. 97-98, 95 Stat. 1341, 7 U.S.C. 4201 et seq., December 22, 1981. This Act directs the Department of Agriculture and other Federal agencies to take steps to assure that their actions do not cause an irreversible conversion of the Nation's farmland to nonagricultural uses. "Farmland," as defined in the Act in 7 CFR 657.5, may include land currently used to produce livestock and timber.

21. Annual Appropriation Act of the Department of the Interior and Related Agencies. This Act provides the conditions for which the BLM may use appropriated funds in the soil, water, and air programs for the fiscal year for which it was passed.

B. Executive Orders.

1. Executive Order (Public Water Reserve No. 107) of April 17, 1926 (36 Stat. 847). Important springs and waterholes on public lands were withdrawn and reserved for public use.

2. Executive Order 11514, March 5, 1970, as amended by Executive Order 11991, May 24, 1977. This amended Order states that the Federal Government shall provide leadership in protecting and enhancing the quality of the Nation's environment to sustain and enrich human life. It provides for monitoring, evaluation, and control on a continuing basis of the activities of each Federal agency so as to protect and enhance the quality of the environment. Agencies shall also develop programs and measures to protect and enhance environmental quality, and exchange data and research results and cooperate with other agencies to accomplish the goals of the NEPA.

3. Executive Order 11738, September 10, 1973. This Order directs each Federal agency to enforce the Clean Air Act and the Clean Water Act in the procurement of goods, materials, and services.

4. Executive Order 11752, December 17, 1973. This Order mandates that Federal agencies shall provide national leadership to protect and enhance the quality of air, water, and land resources through compliance with applicable Federal, State, interstate, and local pollution standards. This order cross-references the need to comply with several environmental acts such as the Clean Air Act, Federal Water Pollution Control Act, Solid Waste Act, Noise Control Act, Insecticide and Pesticide Acts, and NEPA.

5. Executive Order 11988, May 24, 1977, Floodplain Management, as amended by Executive Order 12148. Under the amended Order, each Federal agency is directed to take action to avoid the long- and short-term adverse impacts associated with the occupancy and modification of floodplains. Agencies are further required to avoid direct or indirect support of floodplain development whenever there is a practicable alternative.

6. Executive Order 11990, May 24, 1977, Protection of Wetlands. This Order directs Federal agencies to take action to minimize the destruction, loss, or degradation of wetlands and to preserve and enhance the natural and beneficial value of wetlands in carrying out programs affecting land use.

7. Executive Order 12322, September 17, 1981. Under this Order, any report, proposal, or plan relating to a Federal or federally assisted water and related land resources project or program must be submitted to the Director, Office of Management and Budget, before submission to Congress.

C. Circulars.

1. OMB (Office of Management and Budget) Circular A-67 (August 28, 1964). This Circular provides guidelines for coordination of water data activities and states that the U.S. Geological Survey shall acquire basic water data on the water resources of the Nation. It further states that other agencies shall acquire special water data in support of their respective missions and that these activities be closely coordinated to assure effective and economical management of resources.

2. Circular A-78, Reporting Requirements in Connection with Prevention, Control, and Abatement of Air Pollution at Existing Federal Facilities.

3. Circular A-81, Reporting Requirements in Connection with Prevention, Control, and Abatement of Water Pollution at Existing Federal Facilities.

a. Requires Federal agencies to:

(1) Meet water quality standards and related plans which States have developed under the Federal Water Pollution Control Act.

(2) Consult with the Secretary of the Interior at the earliest feasible time to determine standards applicable to particular facilities and, otherwise, cooperate with him/her.

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i. Executive Order 11988, May 24, 1977, Floodplain Management, as amended by Executive Order 12148. Under the Executive Order, each Federal agency is directed to take action to avoid the long- and short-term adverse impacts associated with the occupancy and modification of floodplains. Actions are further required to avoid direct or indirect support of floodplain development wherever there is a practicable alternative.

j. Executive Order 11990, May 24, 1977, Protection of Wetlands. This order directs Federal agencies to take action to minimize the destruction, loss, or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands in carrying out programs affecting land use.

k. Executive Order 12088, October 13, 1978. Under this order, any [illegible] [illegible] the Director, Office of Management and Budget, before submittal to Congress.

5. Objectives.

a. [illegible]

b. [illegible]

c. [illegible]

d. [illegible] Federal agencies by:

(1) [illegible]

e. [illegible]

(3) Cooperate with State and local pollution control agencies and with other Federal agencies in the evaluation of their pollution control needs.

4. Circular A-97, Specialized and Technical Services to State and Local Governments. Sets forth rules and regulations to effect Title III of the Intergovernmental Cooperation Act authorizing Federal agencies to provide reimbursable technical services to State and local governments.

.04 Responsibility. Responsibilities described below are commensurate with those identified in approved functional statements (see BLM Manual Sections 1211, 1212, 1213, 1214, and 1216).

A. The Director and Associate Director are responsible for all aspects of policy analysis and formulation and program development relating to soil, water, air, and watershed management in the Bureau. This responsibility is exercised through the Deputy Director for Lands and Renewable Resources and the Assistant Director for Renewable Resources.

B. The Service Center Director is responsible for providing soil, water, watershed, and air related technical support upon request from the Headquarters Office and from State Directors and their staffs.

C. State Directors are responsible for formulating policy (within limits delegated by the Director) and for developing, directing, and coordinating a statewide soil, water, and air resource and watershed management program.

D. District Managers are responsible for formulating policy (within limits delegated by State Directors) and for developing, directing, and coordinating a Districtwide soil, water, and air resource and watershed management program.

E. Resource Area Managers are responsible for implementing District, State, and Bureau soil, water, and air resource, and watershed management policies and programs within their designated areas of jurisdiction.

.05 References (reserved).

.06 Policy. It is the policy of BLM to:

A. Manage the public lands in a manner that will protect and improve the quality of the soil, water, and air resources and watershed values associated with public lands.

B. Obtain and keep current needed soil, water, and air resource information to support the various planning and multiple-use management activities associated with BLM administered public lands.

C. Stop the deterioration of public lands due to accelerated erosion and runoff and rehabilitate those areas where watershed values are significantly below their potential.

D. Coordinate the BLM's soil, water, and air quality activities with the related programs of State, local, and other Federal agencies and departments.

E. Provide for compliance with applicable pollution control laws, including State and Federal air, water, or other pollution control standards, programs, or implementation plans.

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.06 Policy. It is the policy of the BLM to:

a. Manage the public lands in a manner that will protect and improve the quality of the soil, water, and air resources and watershed values associated with public lands.

b. Provide and keep current needed soil, water, and air resource information to support the resource planning and multiple-use management activities associated with the administered public lands.

c. Stop the deterioration of public lands due to accelerated erosion and runoff and rehabilitate those areas where watershed values are significantly below their potential.

d. Coordinate the soil, water, and air quality activities with the related programs of States, local, and other Federal agencies and organizations.

e. Provide for compliance with applicable pollution control laws, including State and Federal air, water, or noise pollution control standards, programs, or implementation plans.

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Glossary of Terms

watershed: the area contained within a surface hydrologic drainage divide above a specified point on a stream.

watershed management: the use, regulation, and treatment of water and land resources of a watershed to accomplish stated objectives, primarily the production and protection of water supplies and water-based resources, including the control of erosion and floods and the protection of aesthetic values associated with water.

watershed values: soil productivity and stability and the storage, yield, quality, and quantity of surface and subsurface waters.

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.01 Purpose. This Manual Section defines the policies of the Bureau of Land Management's (BLM) Soil Resource Management Program with specific emphasis on the conduct of soil surveys and their related functions.

.02 Objectives. The Soil Resource Management Program is designed to provide guidance to managers and resource specialists to:

A. Prevent impairment of soil productivity due to accelerated soil loss or physical or chemical degradation of the soil resource.

B. Ensure that Bureau management actions and objectives are consistent with soil resource capabilities.

.03 Authority. The Soil Resource Management Program is conducted under these major authorities, Executive Orders, and Memoranda of Understanding (MOU). (See Manual Section 7000.03.)

A. Desert Land Act of 1977, as amended, Chapter 107, 19 Stat. 377 (43 U.S.C. 321 et seq.; March 3, 1877).

B. Economy Act of 1932, as amended, P.L. 72-211, 47 Stat. 417 (31 U.S.C. 686; June 30, 1932).

C. Taylor Grazing Act of 1934, as amended, P.L. 73-482, 48 Stat. 1269 (43 U.S.C. 315; June 28, 1934).

D. Soil Conservation and Domestic Allotment Act of 1935, as amended, P.L. 74-46, 49 Stat. 163 (16 U.S.C. 590; April 27, 1935).

E. Revested Oregon and California Railroad and Reconveyed Coos Bay Wagon Road Grant Lands Act of 1937, as amended, P.L. 75-405, 50 Stat. 874 (43 U.S.C. 1181; August 28, 1937).

F. Soil Information Assistance for Community Planning and Resource Development Act of 1966, P.L. 89-560, 80 Stat. 706 (42 U.S.C. 3271 et seq.; September 7, 1966).

G. Federal Land Policy and Management Act of 1976, as amended, P.L. 94-579, 90 Stat. 2743 (43 U.S.C. 1701 et seq.; October 21, 1976).

H. Surface Mining Control and Reclamation Act of 1977, P.L. 95-87, 91 Stat. 445 (30 U.S.C. 1201 et seq.; August 1977).

I. Soil and Water Resources Conservation Act of 1977, P.L. 95-192, 91 Stat. 1407 (16 U.S.C. 2001 et seq.; November 8, 1977).

J. Public Rangelands Improvement Act of 1978, P.L. 95-514, 92 Stat. 1803 (43 U.S.C. 1901 et seq.; October 25, 1978).

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.01 Purpose. This Manual Section outlines the policies of the Bureau of Land Management's (BLM) Soil [illegible] Management Program with specific emphasis on the [illegible] of soil [illegible] and their [illegible] functions.

.02 Objectives. The Soil Resource Management Program is designed to provide guidance to managers and [illegible] specialists to:

A. Prevent degradation of soil productivity [illegible] or [illegible] soils [illegible] physical or chemical [illegible] of the soil resource.

B. Ensure that [illegible] management actions and activities are [illegible] which will [illegible].

.03 Authority. The soil resource management program is conducted under these major authorities, Executive Orders and regulations [illegible] (see [illegible] Section [illegible]):

A. [illegible] Act of [illegible], as amended, Chapter [illegible], [illegible] Stat. [illegible] ([illegible] U.S.C. [illegible]; March 1, [illegible]).

B. [illegible] Act of [illegible], as amended, P.L. [illegible] Stat. [illegible] ([illegible] June 30, [illegible]).

C. Taylor Grazing Act of 1934, as amended, P.L. 73-482; 48 Stat. 1269 (43 U.S.C. 315; June 28, 1934).

D. Soil Conservation and Domestic Allotment Act of 1935, as amended, P.L. [illegible] Stat. 163 (16 U.S.C. 590a; April 27, 1935).

E. [illegible] Act of [illegible], as amended, P.L. [illegible] Stat. [illegible] ([illegible] U.S.C. [illegible]; August [illegible]).

F. [illegible] Act of [illegible], P.L. [illegible] Stat. [illegible] ([illegible]).

G. [illegible] Act of [illegible], as amended, P.L. [illegible] Stat. [illegible] ([illegible] U.S.C. [illegible]; October [illegible]).

H. [illegible] Act of [illegible], P.L. [illegible] Stat. [illegible] ([illegible]).

I. [illegible] Act of [illegible], P.L. [illegible] Stat. [illegible] ([illegible]).

J. [illegible] Act of [illegible], P.L. [illegible] Stat. [illegible] ([illegible]).

K. Farmland Protection Policy Act of 1981, Title XV, Subtitle I of P.L. 97-98, 95 Stat. 1341 (7 U.S.C. 4201 et seq.; December 22, 1981).

L. Executive Order 11514, March 5, 1970.

M. Executive Order 11611, February 8, 1972.

N. Memorandum of Understanding between the BLM, U.S. Department of the Interior, and the Soil Conservation Service (SCS), U.S. Department of Agriculture (USDA), Relative to the Making of Soil Surveys on Lands Administered by the Bureau of Land Management, July 8, 1978.

.04 Responsibility. (See Manual Section 7000.04.)

.05 References.

A. Manual Section 7000.

B. National Soils Handbook (NSH), USDA-SCS, 430-VI-NSH, issued July 1983. The NSH serves as a technical supplement to this Manual Section, providing operational procedures for the National Cooperative Soil Survey (NCSS) program. References to specific portions of the NSH appear throughout this Manual Section.

C. Soil Survey Manual (SSM), USDA Handbook No. 18, issued August 1951, and amendments. The SSM serves as a technical supplement to this Manual Section, providing the major principles and concepts for making and using soils surveys and the standards and conventions for describing soils. References to specific portions of the SSM appear throughout this Manual Section.

.06 Policy. It is the policy of the BLM to:

A. Collect and maintain soil resource information at a level of intensity consistent with management needs and in accordance with the NCSS program.

B. Develop, test, and apply soil interpretations to guide the use and management of the soil and related resources.

.07 National Cooperative Soil Survey (NCSS). The Bureau is a member agency of the NCSS program. The NCSS program is a joint effort of cooperating Federal agencies, land-grant universities, and other State and local agencies to describe, classify, map, interpret, and promote the use of soil information. The Bureau recognizes and adopts NCSS standards for the collection and interpretation of soils data. This strengthens the Bureau's soil program, but carries with it the responsibility to actively participate in NCSS efforts to develop, test, and update standards to ensure that Bureau needs are adequately addressed.

E. Farmland Protection Policy Act of 1981, Title 15, Subtitle I of P.L. 97-98, 95 Stat. 1341 (7 U.S.C. 4201 et seq.; December 22, 1981).

F. Executive Order 11514, March 5, 1970.

G. Executive Order 11644, February 8, 1972.

H. Memorandum of Understanding between the BLM, U.S. Department of the Interior, and the Soil Conservation Service (SCS), U.S. Department of Agriculture (USDA), Relating to the Conduct of Soil Surveys on Lands Administered by the Bureau of Land Management, July 8, 1974.

.06 Responsibility. (See Manual Section 7000.06.)

.07 References.

A. Manual Section 7000

B. National Soils Handbook (NSH) (USDA-SCS 430-VI-NSH, issued July 1983). The NSH serves as a technical supplement to this Manual Section, providing operational procedures for the National Cooperative Soil Survey (NCSS) program. References to specific portions of the NSH appear throughout this Manual Section.

C. Soil Survey Manual (1951), USDA Handbook No. 18, issued August 1951, and supplements. The SSM serves as a technical supplement to this Manual Section, providing the basic principles and concepts for making and using soils surveys and the procedures and standards for describing soils. References to specific portions of SSM and NSH appear throughout this Manual Section.

.08 Policy. It is the policy of the BLM to:

A. Acquire and maintain soil resource information at a level of detail consistent with management needs and in accordance with the NCSS program.

B. Maintain, renew and apply soil information in order to guide the use and management of BLM soil and related resources.

[illegible]

7100 - SOIL RESOURCE MANAGEMENT

.1 Soil Resource Management Program. The BLM's Soil Resource Management Program is administered as part of the Soil, Water, and Air Management activity.

.11 Function. The Program has two distinct, though closely related, functions.

A. Watershed Management. Soil and water are basic components of any watershed. Accordingly, soil scientists and hydrologists provide disciplinary expertise for sound watershed management on the public lands.

B. Support Services. The Soil Resource Management Program also provides support services to other resource activities. These are called basic soil services. Such service provides support to other resource activities that include advice, counsel, onsite evaluations, and specialized studies. More specific information about basic soil services is covered in the NSH, Section 600.03-9.

.2 Soil Survey. Soil survey is not simply soil mapping. It is the systematic examination, description, classification, mapping, and interpretation of the soil resource in a given geographic area. Effective and efficient management of Bureau-administered lands depends on the reliability and timeliness of such information.

.21 Operations Management. To identify soil resource information needs, to coordinate BLM activities with other members of the NCSS program, and to assure a smooth flow of work, cooperative efforts must be accomplished at the national, regional, State, and District levels.

A. National Level.

1. The National Long-Range Soil Survey Plan is developed and maintained in the BLM Headquarters Office. It shows the status of soil survey work on Bureau-administered lands and identifies future data needs and Bureauwide priorities. The Plan aids in the budgeting of funds and the scheduling of work for the efficient and orderly completion of soil survey on all Bureau-administered lands.

2. National soil survey work-planning conferences are held in odd-numbered years to discuss and resolve issues of national concern to the NCSS program. (See NSH, Section 600.03-1.) A Bureau representative serves as a permanent member of the conference steering committee.

3. A national MOU between the BLM and the SCS guides the actions of each agency in the conduct of cooperative soil survey work on Bureau-administered lands.

B. Regional Level.

1. Regional soil survey work-planning conferences are held in even-numbered years to discuss and resolve issues of regional concern to the NCSS program. One Bureau representative from each of the 11 Western States (Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, and Wyoming) and one representative from the Denver Service Center (DSC) serve as voting members of the Western Regional Conference. (See NSH, Section 600.03-2.) Bureau representatives to other regional conferences are recommended by the Headquarters Office as deemed necessary.

C. State Level.

1. The State Long-Range Soil Survey Plan is developed and maintained in the State Office. It shows the status of soil survey on Bureau-administered lands within the State and identifies future data needs and statewide priorities. The Plan aids in the budgeting of funds and the scheduling of work to meet management objectives. (See NSH, Section 600.03-3.)

a. Determining Priorities. Priorities for soil surveys within the State are determined by the State Director. The following factors should be considered in setting priorities:

(1) Information needs in support of the Bureau Planning System.

(2) Baseline data needs for monitoring studies.

(3) Other proposed or anticipated actions where soil-related effects, influences, or impacts will be analyzed.

b. Scheduling Soil Survey Work. As a NCSS cooperator, the BLM must coordinate soil survey activities with the SCS to maintain uniform workflow through the publication stage. (See NSH, Sections 601.04-5 and 601.04-6.) The Computer Aided Scheduling of Published Soil Surveys (CASPUSS) system is designed to compile schedules and standardize the administrative data necessary to coordinate the NCSS program. (See NSH, Exhibits 601-1 and 601-2.)

2. State soil survey conferences are held annually to discuss and resolve issues of statewide concern to the NCSS program. The Bureau is represented by the State soil scientist or a qualified designee. This conference provides an opportunity to review the State long-range plan (see .21C1) and to coordinate soil survey work schedules in support of the Bureau's annual work planning process.

3. A State-level MOU should be developed among the appropriate cooperators, generally the BLM, the SCS, and the State Agricultural Experiment Station. This agreement defines the general responsibilities of each cooperator for all soil surveys on Bureau-administered lands within the State. (See NSH, Section 601.02-1(a).)

4. A survey area MOU (work plan) <u>must</u> be developed for each soil survey area containing Bureau-administered land. This work plan may take the form of an annual amendment to the State-level MOU (see .21C3) or a separate MOU. In either case, included are the purpose of the survey, specific design criteria, desired interpretations, and a detailed definition of responsibilities regarding publication, interim reports, quality control, and any cost reimbursement provisions. This work plan should be prepared in close cooperation with the District staff. (See NSH, Section 601.02-1(b).)

D. District Level. A workload analysis should be prepared by the District staff, prior to developing a survey area MOU. This analysis should include a determination of acres to be mapped, personnel available for mapping, additional mapping personnel needs, time requirements for other resource specialists (e.g., range, wildlife, forestry, engineering), vehicle and other equipment needs, etc. The actual procedure and format for the analysis is determined by the State and District staffs. Guidance is given in NSH, Sections 601.04-1 and 601.01-2; although, any method that gives the desired results is acceptable.

.22 Soil Classification and Mapping. The primary objective of any soil survey is to provide reliable soil resource information consistent with the purpose of the survey. To help meet this objective, an experienced soil scientist must serve as the Contracting Officer's Authorized Representative (COAR) on all contract soil surveys. In addition, all soil surveys on Bureau-administered lands must meet the technical standards of the NCSS program.

A. National Cooperative Soil Survey. Standards and procedures for classifying and mapping soils are set forth in the following publications:

1. Soil Taxonomy (USDA Handbook 436, December 1975) and amendments. This publication provides the common base for the organization of knowledge about soils and the standards for their grouping into taxonomic classes. (See NSH, Section 602.00-1.)

2. Soil Survey Manual (USDA Handbook 18, August 1951) and revisions. This Manual provides the fundamental principles and the general procedures for making soil surveys. (See NSH, Section 602.00-2.)

3. National Soils Handbook. The NSH provides policy and procedures for carrying out the NCSS program. (See NSH, Part 600.00, Sections 600.01 and 602.00-3.)

B. Survey Design. Each soil survey must be designed to meet the needs of the users. This requires a knowledge of survey design alternatives and an awareness of management issues and concerns in the survey area.

1. Design Criteria. There are four major attributes of a survey that can be manipulated to meet specific management needs. (See NSH, Section 602.01-5.)

a. Kinds of Mapping Units. There are three main kinds of mapping units used in surveys on Bureau-administered lands. Consociations are dominated by a single component, while associations and complexes have two or more dominant components. (See Glossary of Terms for more detailed definitions.)

b. Components of Mapping Units. Mapping unit components are identified as either soil taxa or miscellaneous areas. Soil taxa are named at some level of soil taxonomy (i.e., Order, Suborder, Great Group, Subgroup, Family, Series). Miscellaneous areas (e.g., badland, rock outcrop) have little or no identifiable soil or have some highly unfavorable attribute which would override most use and management options. The choice of components and the level at which soil taxa are named depends on the use of the survey data. Normally, the soil series will be the basic taxon mapped on Bureau-administered lands. Phases of series will be the most common component of mapping units. Written approval from the Headquarters Office must be obtained prior to establishing a mapping legend which primarily utilizes any category above the series level.

c. Field Procedures. Specific field procedures determine the precision with which the composition of mapping units is described and the accuracy of the mapping unit boundaries. There are four basic procedures: transect, traverse, observation, and air photo interpretation. (See Glossary of Terms for detailed definitions.)

d. Map Scale. The chosen map scale dictates the smallest unit that can be delineated on the map. Generally, this is a 1/4 x 1/4 inch square or a circular area of 1/16 square inch. In practice, this is the smallest unit around which a line can be drawn in which a symbol can be placed. (See SSM, Chapter 2, pages 2-15.)

2. Standard Orders of Intensity. There are five standard orders of soil survey intensity, each defined in terms of the four design criteria listed above (see .22B1). An Order 3 survey is the approved level of intensity for most Bureau-administered rangelands. Surveys of greater or lesser intensity may be conducted on specific sites depending upon resource values and the level of detail needed for management decisionmaking. The characteristics of each level of intensity are given in SSM, Chapter 2, pages 2-14.

C. Quality Control. Soil correlation is a quality control process to ensure that kinds of soil are adequately defined, accurately mapped, and uniformly named in all soil surveys. In practice, the correlation process may be divided into two parts, informal and formal.

1. Informal Correlation. The informal portion involves day-to-day quality control efforts and is the primary responsibility of the survey party leader. Informal correlation also includes periodic field reviews to assist the party leader. In areas consisting of predominantly Bureau-administered land, the Bureau is responsible to ensure that specific provisions of the soil survey work plan, including Field reviews, are carried out. Individual agency responsibilities in the Field review process must be defined in the work plan (see .21C4).

2. Formal Correlation. There are two steps to formal correlation, the field correlation (usually combined with the final Field review) and the final correlation. Formal correlation can be greatly simplified by a conscientious, informal correlation effort throughout the survey. In all survey areas, regardless of land ownership or administration, the SCS is responsible for formal correlation. Cooperative planning and scheduling of correlation and related activities are essential for the SCS to carry out this responsibility in a timely manner. (See NSH, Section 602.004(b)(2).)

.23 Soil Interpretations. Soil interpretations are predictions of soil behavior or soil suitability for specific land uses or management practices. They do not preclude management actions, but rather provide a manager with a reasonable guide to the risks, limitations, and probable outcome of a particular use or practice. The level of intensity of soil mapping and the design of soil map units determine the kind of soil interpretations that can logically be made. Interpretations can be no more specific than the degree of map unit refinement and the displayed mapping detail. Accordingly, interpretive needs should be identified prior to initiation of extensive soil mapping (see .21D). Data for site-specific interpretations are better obtained through onsite evaluations (see .3), since a suitable mapping intensity over an entire survey area would be impractical.

A. Standard Interpretations. Several different soil interpretations have been formally developed, tested, and approved for application through the NCSS program. They appear in NSH, Tables 603-10 through 603-43. These interpretations, when applicable, should be used Bureauwide. Any revision of standard interpretations must be approved in writing by the Headquarters Office.

B. New Interpretations. Additional interpretations not provided for in the standard list (see .23A) are needed for rangeland and forestland applications. Examples include soil interpretations for mantle stability (landslide hazard), prescribed burning, rangeland seeding, use of specialized equipment, fence construction, wildfire rehabilitation, grazing systems, unsurfaced roads, plantability of tree seedlings, and Desert Land Entry (DLE) clearances.

1. Initiation. The need for new interpretations is often identified at the District or Resource Area level, though may originate at any level. The initial step is to select preliminary soil criteria that relate to the use or practice in question. Criteria consist of specific soil properties and rating classes. These criteria are based on professional judgment and any pertinent technical guides or other available information from the BLM; other Federal, State, or local agencies; universities; professional societies; and scientific literature. The source and rationale for criteria must be documented as part of the interpretation. Preliminary interpretations are then submitted to the appropriate State Office(s) for testing and coordination.

2. Testing and Coordination. Testing consists of evaluating the specific criteria for adequacy and verifying the rating classes against actual field observations and any available records on the results of similar actions. Specific assignments should be made for testing (e.g., District soil scientists, DSC soil scientists) and the responsibilities programmed and tracked through the annual work plan process. This ensures timely completion of testing. To establish broad credibility for a new interpretation, other resource specialists from within the BLM and from participating NCSS agencies in the State should be consulted for review and for any available data by which to evaluate the new interpretation. The State Director or designee is responsible for this coordination during the testing phase.

3. Preparation of Final Interpretation. When testing is completed and all comments, suggestions, and test results assembled, a final interpretation is prepared. This may be accomplished by the appropriate State Office staff specialist or by any other individual or group appointed by the State Director. Each new interpretation must include the following elements:

a. Assumptions. (See NSH 603.03-3(d)(1) for example.)

b. References (pertinent sources of information in support of interpretation criteria).

c. Criteria (soil properties and rating classes). (See NSH Table 603-24 for example.)

d. Explanation of rating classes. (See NSH 603.03-3(e)(2) for example.)

4. Approval. When the final interpretation has been prepared, it must be approved in writing by the State Director or designee prior to extensive application. Once approved, the interpretation becomes a State supplement to this Manual Section (i.e., 7100). Other States, upon written approval by the appropriate State Director or designee, may adopt the interpretation for use. Coordination among States should preclude major differences in the same or similar interpretations. However, if two or more States approve interpretations for the same use or practice that contain different soil properties, have different rating classes, or otherwise different, the Headquarters Office shall have final authority to require modifications if deemed necessary.

5. Distribution of Interpretations. Following approval of new interpretations, they shall be distributed as follows:

a. Washington Office (WO-200).

b. Denver Service Center (D-400).

c. All State Directors.

d. All District Managers (within approving State).

e. State Soil Scientist, SCS (within approving State).

f. Principal Soil Correlator, SCS National Technical Center, Portland, Oregon.

.24 Survey Investigations. Soil survey investigations are made in support of the soil survey. They provide information on chemical and physical soil properties needed for characterization, interpretation, and classification. (See NSH, Part 604.) Laboratory support needs should be addressed in the survey area MOU (see .21C4).

.25 Survey Reports.

A. U.S. Department of Agriculture Series. The SCS has responsibility for publishing soil survey reports for the NCSS program as part of a formal USDA publication series. Guidelines for the publication of surveys on lands administered by Federal agencies are given in NSH, Section 605.10. Specific agency responsibilities for manuscript preparation and related duties should be addressed in the survey area MOU (see .21C4).

B. Interim Reports. Prior to publication of a final survey report, the BLM may use or publish interim information as required, for within Bureau use. Where the SCS or other agency is conducting a survey on Bureau-administered lands, the need for interim information should be clearly documented in the survey area MOU (see .21C4). Interim publications should give appropriate credit to other agencies involved in making the survey. (See NSH, Section 605.08(b).)

.3 Onsite Evaluations. Most soil surveys on Bureau-administered lands are conducted at an Order 3 level of intensity. This level is adequate for general planning purposes but is not sufficient for site-specific planning, analyses, or project design (e.g., water developments, erosion control structures, road locations, vegetation manipulations, DLE applications). In such cases, onsite evaluations are conducted by soil scientists to evaluate specific soil properties and site characteristics important for project success and to aid in determining design criteria, associated cost factors, and potential problems or hazards.

.31 Reports. The results of onsite evaluations may be reported informally (oral communication) or in formal written reports.

A. Required Reports. Formal written reports are required whenever the proposed action involves:

1. A legal appeal or litigation or where such action is expected.

2. Estimated project costs that exceed $1,000.

3. The potential for serious environmental damage or safety hazards either onsite or offsite.

B. Report Format. Formal written reports will contain the following information as a minimum:

1. Name and title of evaluator.

2. Date of evaluation.

3. Location.

4. Purpose.

5. Procedures or techniques employed.

6. Findings (e.g., observations, revised or more detailed soil map).

7. Applicable alternatives (if appropriate).

8. Conclusions and/or recommendations.

C. Environmental Analysis. Recommendations or conclusions that result from an onsite evaluation shall become a part of any environmental analysis document.

[illegible]

[illegible]

6. Reports. The results of onsite evaluations may be reported informally (oral, memorandum) or in formal written reports.

7. Required Reports. Formal written reports are required whenever the proposed action involves:

1. A legal appeal or litigation of [illegible] is expected.

2. Estimated project costs that exceed [illegible].

3. The potential for serious environmental damage affecting resources either public or private.

8. Report Format. Formal written reports will contain the following information as a minimum:

1. Name and title of evaluator.

2. Date of evaluation.

3. Location.

4. Purpose.

5. Procedures or techniques employed.

6. Findings (e.g. [illegible]).

7. Applicable alternatives (if appropriate).

8. Conclusions and/or recommendations.

9. Environmental Analysis. Recommendations or conclusions that result from an onsite evaluation shall become a part of any Environmental Analysis document.

.4 Soil Information Systems. (Reserved)

.5 Training and Career Development. (Reserved)

Glossary of Terms

-A-

association, soil: a group of soils geographically associated in a characteristic repeating pattern and defined and delineated as a single map unit.

air photo interpretation: plotting boundaries and estimating composition of delineations based on air photo features that have been related to soils and landscape features.

-C-

climax vegetation: the stabilized plant community on a particular site. The plant cover reproduces itself and does not change as long as the environment remains the same.

complex, soil: a map unit of two or more kinds of soils in such an intricate pattern or so small in area that it is not practical to map them separately at the selected scale of mapping. The pattern and proportion of the soils are somewhat similar in all areas.

consociation, soil: a map unit in which one kind of soil or a kind of miscellaneous area dominates each delineation.

-O-

observation: visual checking of landscape features, exposed geological formations, or change exposures of pedons from within or without a delineation to project boundaries and composition from previously determined relations; air photos may be used as guides. This is a less intensive operation than traversing.

-P-

productivity, soil: the capacity of a soil for producing a specified plant or sequence of plants under specific management.

-R-

rangeland: land on which the potential natural vegetation is predominately grasses, grasslike plants, forbs, or shrubs suitable for grazing or browsing. It includes natural grasslands, savannas, many wetlands, some deserts, tundras, and areas that support certain forb and shrub communities.

range site: an area of rangeland where climate, soil, and relief are sufficiently uniform to produce a distinct natural plant community. A range site is the product of all the environmental factors responsible for its development. It is typified by an association of species that differ from those on other range sites in kind or proportion of species or total production.

-S-

soil: the collection of natural bodies on the Earth's surface, in places modified or even made by man of earthy materials, containing living matter and supporting, or capable of supporting, plants out of doors. Soil is a natural medium for the growth of land plants, whether or not it has discernible soil horizons.

soil classification: the systematic arrangement of soils into groups or categories on the basis of their characteristics. Broad groupings are named on the basis of general characteristics, and subdivisions on the basis of more detailed difference in specific properties.

soil management: all activities in soil identification, classification, and interpretation of soil behavior (potential and limitations) related to land use and the sum total of all land treatments, soil productivity, and other special treatments conducted on a soil.

soil survey: A field investigation resulting in a soil map showing geographic distribution of different kinds of soil and an accompanying report that describes, defines, classifies, and interprets for use the different kinds of soil. The interpretations predict how the soil behaves for different uses and responds to various management systems.

-T-

transect: (1) The field procedure of crossing delineations or landscape units along selected lines to determine the pattern of polypedons with respect to landforms, geologic formations, or other observable features. (2) Identifying pedons at regular spaced intervals (i.e., gridding).

traverse: validation of the predicted boundaries or composition of a delineation by entering it or crossing it and identifying pedons at selected or random positions.

.01 Purpose. This Manual Section presents overall objectives, responsibilities and policies for conducting the Bureau's Water Resources Program.

.02 Objectives.

A. Maintain or improve surface and ground water quality consistent with existing and anticipated uses and applicable State and Federal water quality standards;

B. Minimize the harmful consequences of uncontrolled water flows on or arising from Bureau-administered lands;

C. Provide for the physical andlegal availability of water to facilitate authorized uses of the public lands.

.03 Authority. The authorities for the water resources program are listed and annotated in BLM Manual Section 7000.03.

.04 Responsibility.

A. The Director and Deputy Director are responsible for:

1. Establishing Bureauwide objectives, formulating and analyzing national level policies, and settiang national priorities for the conduct of the water resources program;

2. Preparing, evaluating, and revising Bureau Manuals, Handbooks, and Technical References to maintain a current system of policy documentation and program guidance;

3. Providing liaison at the national level with other Federal agencies and ~~other~~ oganizations

4. Ensuring internal coordination between the Water Resources Program and other Bureau Programs.

.01 Purpose. This Manual Section provides overall objectives, responsibilities and policies for conducting the Bureau's Water Resources Program.

.02 Objectives

A. Maintain or improve surface and ground water quality consistent with existing and anticipated uses and applicable State and Federal water quality standards.

B. [illegible] the natural consumption of unappropriated water flows on [illegible] from [illegible] areas.

C. Provide for the physical and legal availability of water to accommodate authorized uses of the public lands.

.03 Authority. The authorities for the water resources program are listed and summarized in [illegible].

.04 Responsibilities

A. The Director and [illegible] are responsible for:

1. Establishing national objectives, formulating and developing national level strategies, and establishing national priorities for the conduct of the Water Resources Program.

2. Preparing, maintaining, and revising Bureau Manuals, Handbooks, and [illegible] necessary to [illegible] of policies and guidance.

3. Coordinating [illegible] at the national level with other Federal agencies and other organizations.

4. Reviewing [illegible] to ensure the Water Resources Program and [illegible] Program.

B. The S<u>e</u>rvice Center Director is responsible for providing technical support to the Headquarters Office and Field Offices by:

1. Responding to Field Office requests for technical assistance and/or training;

2. Developing, testing, evaluating, and making recommendations to the Headquarters Office on the applicability of new technologies for the collection, storage and retrieval, analysis and interpretation, and application of water resources data;

3. Preparing water resource handbooks, technical notes and references, and other field-oriented guidance at the direction of the Headquarters Office;

4. Providing liaison with research agencies, educational institutions, and professional organizations to maintain a "state-of-the-art" level of knowledge in water resources.

C. State Directors are responsible for achieving the Bureau's water resource program objectives (.02) within their respective States by:

1. Interpreting Bureauwide water resource policies, setting State water resource priorities, and preparing supplemental program directives for Statewide application;

2. Providing liaison with other Federal agencies, State agencies, user groups, and adjoining BLM State Offices to ensure a coordinated water resources program;

3. Evaluating Statewide water resource program effectiveness through periodic analyses of related decisions and products (e.g. RMP's, activity plans, monitoring plans);

4. Providing or otherwise making available training and technical support to ensure that water resource program personnel are professionally equiped to comply with established technical standards.

D. District Managers are responsible for achieving Bureau and State water resource program objectives within their respective District boundaries by:

1. Interpreting Bureau and State water resource policies, setting District water resource priorities, and preparing supplemental program directives and guidelines for Districtwide application;

2. Cooperating with other Federal, State, and local agencies, user groups, and adjoining BLM District Offices to ensure a coordinated water resources program;

3. Evaluating Districtwide water resource program effectiveness by periodically reviewing and evaluating Recource Area work accomplishments for technical adequacy and compliance with Bureau, State, and District policies;

4. Maintianing sufficient technical expertise within the District organization and Resource Area organizations to ensure that water resource issues are identified and addressed in accordance with established professional and technical standards.

2. District Engineers are responsible for executing Corps and Navy water resource program activities within their respective District boundaries by:

1. Interpreting Corps and Navy water resource policies, writing detailed water resource objectives, and preparing supplemental program principles and guidelines for District-wide application.

2. Cooperating with other Federal, State, and local agencies, and private organizations and the Governor's Office to assure a coordinated water resources program.

3. Evaluating Navy-generated water resource planning applications by coordinating and evaluating Corps Area work accomplishments for continued success, and compliance with Corps, Navy, and District policies.

4. Investigating unit-level technical assistance within the Inspector organization and District Navy organizations to ensure that water resource issues are identified and addressed in accordance with established Corps-Navy goals and regional standards.

E. Resources Area Managers are responsible for achieving Bureau, State, and District water resource program objectives within their respective Resource Area boundariess by:

1. Conducting water resource inventories to provide baseline data on water sources/uses, water quality, water quantity, and sediment yield;

2. Implementing water resource monitoring to document changes over time in water quality, water quantity, and sediment yield;

3. Analyzing and interpreting water resource and realted data to determine and maintain a record of watershed condition;

4. Protecting and acquiring and/or perfecting water rights to meet multiple-use management needs;

5. Preparing and implementing plans to develop, protect, and/or rehabilitate ~~the~~ water resources.

6. Idnetifying and resolving shortages or deficiences in technical expertise needed to carry out the water resources program in accordance with established professional and technical standards.

.06 Policy.

A. Collect and maintain surface and ground water resource data consistent with land management needs and methodologies found in BLM Handbooks and professionally accepted technical references.

B. Analyze and interpret water resource data to set resource management objectives; comply with State and Federal authorities; and assess environmental impacts from land use activities.

C. Implement water resource management activities through the three tier BLM Resource Management Planning process.

COURSE 7000-1 CLASS EXERCISE

USING ONE OR TWO SENTENCES, VERY BRIEFLY DESCRIBE A SIGNIFICANT SOIL OR WATER RESOURCE ISSUE OR PROBLEM YOU ARE CURRENTLY INVOLVED WITH.

4/4/85

7000 SOIL, WATER, AND AIR RESOURCES

7100 SOIL RESOURCE
.1 Soil Resource Program
.2 Soil Survey Operations
.3 Soil Classification and Mapping
.4 Soil Survey Reports
.5 Soil Interpretations
.6 Site-Specific Evaluations
.7 Soil Information Systems

7200 WATER RESOURCES

7210 Watershed Condition Analysis

7220 Watershed Activity Planning

7230 Groundwater

7240 Water Quality

7250 Water Rights

7260 Floodplains

7300 AIR RESOURCE
.1 Air Resource Program
.2 Air Resource Management Activities
.3 Air Resource Inventory
.4 Air Resource Monitoring
.5 Air Resource Modeling
.6 Air Resource Training and Education

Guidance System

Legislation, Executive Orders, and Court Orders: Taylor Act, FLPMA, PRIA, etc.

Grazing Regulations: 43 CFR 4100 (Oriented Toward the Public)

Departmental Manuals: (are typically general instructions)

BLM Directives

Long Term Directives (Manual System)

Manual Sections: Policy, and Standards (Written for Managers)	Manual Handbooks: Required Procedure and Standards (detailed); written for Staff/Technical personnel	Reference System: Optional Procedure and Technical Information
1622 - Supplemental Program Guidance for Renewable Resources Programs (WO IM 86-136)		
4100 - Grazing Administration (Excl. of Alaska) (Rel. 4-69, 6/20/84)		
4110 - Qualifications and Preference (Rel. 4-70, 6/20/84)	H-4110-1 - Qualifications and Preference (Rel. 4-71, 6/20/84)	
4120 - Grazing Management (Rel. 4-72, 6/20/84)	H-4120-1 - Grazing Management (Rel. 4-73, 6/20/84)	
4130 - Authorizing Grazing Use (Rel. 4-74, 7/2/84)	H-4130-1 - Authorizing Grazing Use (Rel. 4-75, 7/3/84)	
4150 - Unauthorized Grazing Use (Rel. 4-76, 5/16/84)	H-4150-1 - Unauthorized Grazing Use (Rel. 4-77, 7/3/84)	
4160 - Administrative Remedies (Rel. 4-78, 6/20/84)	H-4160-1 - Administrative Remedies (Rel. 4-79, 7/3/84)	
4400 - Rangeland Inventory, Monitoring, and Evaluation (Rel. 4-64, 12/1/83)		TR-4400-1 - Rangeland Monitoring: Planning for Monitoring (p-205)
4410 - Ecological Site Inventory (Rel. 4-80, 7/12/84)	H-4410-1 - National Range Handbook (Rel. 4-81, 7/12/84)	TR-4400-2 - Rangeland Monitoring: Actual Use Studies (p-206) TR-4400-3 - Rangeland Monitoring: Utilization Studies (p-207) TR-4400-4 - Rangeland Monitoring: Trend Studies (p-208) TR-4400-7 - Rangeland Monitoring: Analysis, Interpretation, and Evaluation (p-209)
1740 - Renewable Resource Improvements and Treatments (Rels. 1-1427 and 1-1417) 6/28/85 and 9/3/85	H-1740-1 - Renewable Resource Improvement and Treatment Procedures; draft now being revised	
1741 - Renewable Resource Improvements, Practices, and Standards (Rel. 1-1418, 4/11/85)	H-1741-1 - Fencing (Rel. 1-1419, 5/20/85)	R-1741-1 - Revegtation Equipment Catalog (p-229)
1742 - Emergency Fire Rehabilitation (Rel. 1-1423, 8/8/85)	H-1742-1 - Emergency Fire Rehabilitation (Rel. 1-1424, 8/8/85)	
1743 - Renewable Resource Investment Analysis (Rel. 1-1429, 4/11/85)	H-1743-1 - Resource Investment Analysis User Handbook for the SageRam Computer Program (Rel. 1-1430, 9/9/85)	
		T/N 337 - Hydrologic Risk and Return Period for Water Related Projects
7000 - Soil, Water, and Air Management (Rel. 7-85, 3/8/84)		T/N 366 - Gully Erosion
7100 - Soil Resource Management (Rel. 7-87, 8/15/84)		T/N 369 - Considerations in Rangeland Watershed Monitoring
7221 - Floodplain Management (Rel. 7-66, 2/14/79)		T/N 368 - A Runoff and Soil-Loss Monitoring Technique Using Paired Plots
7240 - Water Quality (Rel. 7-63. 3/19/84)		TR 4341-1 - Channel Cross Section Surveys and Data Analysis
7250 - Water Rights (Rel. 7-86, 3/19/84)		TR 7230-1 - Guidelines for Conducting Groundwater Studies in Support of Resource Activities T/N 369 - 1980-82 Salinty Status Report Hydrologic Design and Analysis Programs T/N 370 - Predictive Model for Estimating Maximum Summer Stream Temperatures in Western Oregon Reynolds Creek Summary Report Instream Flow Guidelines - BLM

Short Term Directives: Instruction and Information Memos

THE BUDGET PROCESS

The purpose of the budget is to obtain funding necessary for the Bureau to carry out its responsibilities and accomplish program objectives.

The name of the game at all organizational levels is competition. The Department of Interior competes with all other Executive Branches (e.g. Agriculture, Defense, etc.). Within Interior, the Ass't. Secretary for Lands and Minerals Management, who has juristiction over the BLM, competes with the other four Ass't. Secretaries and a variety of Secretarial Offices. The BLM competes with all other agencies under the same Ass't. Secretary (MMS,OSM). Your State competes with other states within the BLM. Your District competes with other Districts in the State. Your Resource Area competes with other Area Offices in your District.

The Bureau's budget is prepared and implemented in a cycle which takes approximately 3 years from Package Directives through implementation of the Annual Work Plan and Operating Budget (see Figure 1).

Increased delegation of authority to the State Directors has resulted in more flexibility and increased financial rersponsibility for the States in managing their Operating Budget. In the past, nearly the entire Operating Budget (i.e. $, #WM, equipment, procurement, units of accomplishment, travel, etc.) was controlled by the Washington Office. Now, only total dollars by subactivity, major accomplishments (MBO), travel, and FTE's are controlled. The State Directors can establish the funding levels of each object class within total dollars available by subactivity and adjust them during the fiscal year (FY) as necessary. However, only the WO (Div. Budget) can officially adjust the controlled items (such as subactivity funding levels between States).

To better understand the Budget Process, there are several definitions and concepts which you need to know.

<u>Cost targets</u> The Division of Budget (WO) establishes a cost target for each subactivity on a Bureauwide basis. In turn, each WO Program Office establishes a cost target for each State, each State establishes a cost target for each District, and each District establishes a cost target for each Resource Area. Cost targets are given to the field in what is called "direct dollars".

<u>Direct dollars</u> The appropriation from Congress is in "total dollars". Total dollars minus the estimated salary and benefits paid to employees during leave status (leave surcharge) equals direct dollars. Leave is a legitimate cost which must be funded. However, since BLM personnel can charge their time to more than one program depending on the work they are doing, leave costs are funded on a Bureauwide basis and each subactivity is surcharged for leave costs according to its share of work months used. The money to fund the leave account is deducted from the total dollars available in each subactivity and is held centrally to pay for all types of leave taken.

<u>Budget workyear</u> The normal budget workyear per position is 10 WM's. This is the result of funding in direct dollars as discussed above (i.e. deducting approximately 2 WM's for leave).

<u>Full time equivalent (FTE)</u> An FTE equals one compensable work year (i.e. 12 WM's of paid time). The Bureau has an FTE ceiling established by the Department of Interior. In turn, the WO (Div. Budget) sets a ceiling for each State. It is important to remember that FTE's and positions are NOT the same even though most states control FTE usage by position control.

B U D G E T   C Y C L E

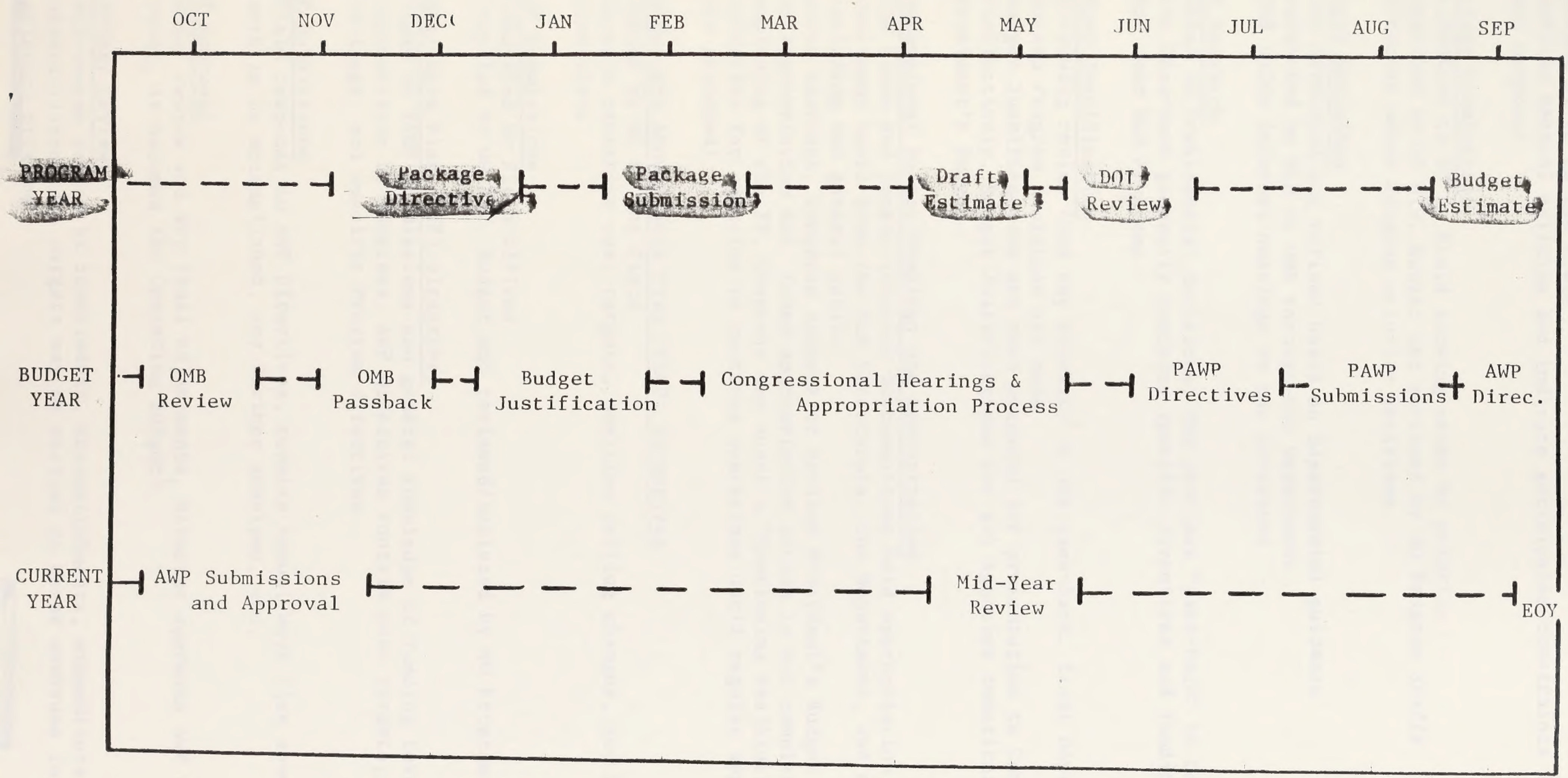


FIGURE 1

Package Directives
--issued by WO to the Field
--outline general policies and indicate anticipated constraints in funding and manpower

Package Submissions
--submitted to WO by Field showing needs by priority
--compiled by WO Div. Budget and reviewed by WO Program Staffs
--Director makes Program priority decisions

Budget Estimates
--are developed and refined based on Departmental guidance
--submitted by BLM to OMB through the Department
--OMB holds informal hearings on the Estimates

OMB Passback
--based on Presidential decisions, OMB provides "pass-back" to Department
--the Pass-back generally contains specific directives and funding levels for most BLM Programs

Budget Justification
--following review (and any appeals) of OMB pass-back, final Department and Bureau Program decisions are made
--Budget Justifications are then prepared for presentation to Congress (Collectively, Budget Justifications for all agencies constitute the President's Budget

Congressional Budget Hearings and Appropriation
--the House and Senate Interior Subcommittees hold appropriation hearings
--testimony heard from the BLM Directorate, the Department, and other parties including the general public
--after hearings, Congress accepts or revises President's Budget and passes an Appropriation Act (when appropriation action is not completed by the beginning of the FY, Congress may enact a "Continuing Resjolution" to give authority for agencies to continue operations until regular appropriations are approved)

Preliminary Annual Work Plan (PAWP) Directives
--issued by WO to the Field
--contain tentative cost targets, position ceiling changes, and Program directives

PAWP Submissions
--submitted by Field Offices
--compiled by WO Div. Budget and reviewed/analyzed by WO Program Staffs

Annual Work Plan (AWP) Directives
--based on PAWP submissions and general knowledge of funding levels to be appropriated by Congress, AWP Directives contain cost targets, personnel ceilings, and specific Program directives

AWP Submissions
--Field responds to AWP Directives, submits Annual Work Plan showing work to be accomplished, any further problems, etc.

AWP Approval
--after review and any final adjustments, Director approves AWP (at this point, it becomes the Operating Budget)

Mid-Year Review
--mid-course review of commitments, accomplishments, expenditures, etc.
--underutilized cost targets may be shifted to cover overruns in high priority programs

PLANNING

OVERVIEW OF RESOURCE MANAGEMENT PLANNING

I. Instructional Objectives:

At the conclusion of this session, the participant will be able to:

A. Define the steps followed in preparing a resource management plan;

B. Identify the parties usually involved in preparing a resource management plan and their respective roles; and

C. Describe the level and type of decisions usually made in a resource management plans.

II. Topical Outline:

A. Setting the Stage
All BLM plans involve choosing among alternative courses of action. They vary in terms of the nature of the products produced, the process followed, and the parties involved.

B. The Process
What are the steps in preparing an RMP or plan amendment? Which ones always involve soil, water and air? What are "issues" and what are "planning criteria"? What's distinctive about the RMP process?

C. The Parties
Who are the internal and external parties involved in preparing an RMP? What are their respective roles?

D. The Products
What are the outputs of resource management planning? What kinds of decisions should an RMP contain, especially with respect to soil, water and air? What should be in the supporting record? What follows the RMP?

Biographical Sketch

Kit Muller
Office of Planning, WO-202
FTS 653-8830

CAREER EXPERIENCE:

1980 to 1981 - Office of Policy Analysis and Program Development
Washington, D.C.

1981 to 1984 - Office of Planning
Washington, D.C.

Prior to my employment with the Bureau, I worked for a number of public interest groups, primarily on coal and electric utility related matters.

EDUCATION: BA - Social Anthropology - Harvard Univeristy
MA - Public Policy/Economics - University of California, Berkeley

WATERSHED CONDITION ANALYSIS

Course Objectives: Upon completion of this segment, students should be able to:

1. List the four components which can be used in watershed condition analysis;

2. Describe at least two ways to determine the "tolerance level" for a watershed analysis component;

3. Using watershed condition classes and any other criteria you choose, depict and explain selective management categories to interpret watershed condition.

Topic Outline

I. Analysis Design

- A. Management Needs
- B. Area Stratification
- C. Component Selection

II. Determining Watershed Condition

- A. Characterizing the Present (Existing Situation)
- B. Establishing Standards (Tolerance)
- C. Condition Class (Existing vs. Tolerance)

III. Management Interpretation

- A. Purpose
- B. Criteria for Interpretation
- C. Example

Course: 7000-1
Instructor: D. Muller
Hooper

SOIL AND WATER RESOURCE ACTIVITY PLANNING

1. Identify sources of guidance for use in setting soil and water resource management objectives.

2. List several types of activity plans and know when not to use certain plans.

3. Prepare an activity plan outline.

Topic Outline:

I. Soil and Water Resource Improvement Objectives

   A. Guidance - RMP (Condition Analysis Results)

   B. Guidance - Bureau Planning Policy

II. Plan and Implement Soil and Water Resource Improvements

   A. Activity Plans (general)

   B. Watershed Management Plans

   C. Activity Plan Monitoring

III. Plan Contents - District Perspective

   A. Problem Identification and Analysis

   B. Management Objectives and Alternative Options

   C. Monitoring Studies and Evaluation

Daniel P. Muller

Bureau of Land Management
Washington, D.C.
202/653-9210
FTS 653-9210

PERSONAL DATA

Birth Date--April 7, 1954

EDUCATIONAL DATA

1977 B.S. in Forest Watershed Science from Colorado State University.

EMPLOYMENT DATA

1977 to 1978 Hydrologist on the White River National Forest, Glenwood Springs, Colorado.
Duties: Instream Flow Study, Water Quality Inventory

1978 to 1980 Hydrologist in the Bureau of Land Management, Glasgow, Montana.
Duties: Water Resource Inventories, Oil and Gas Surface Protection

1980 to 1985 Hydrologist in the Bureau of Land Management, Lewistown, Montana.
Duties: Water Rights, Flood Routing Study, Watershed Activity Plan, District Program Leader

1985 to Present Hydrologist in the Bureau of Land Management, Washington, D.C.
Duties: Program Leader-Water Resources Program, Interagency Coordination

Resume

Ron Hooper District Hydrologist Cedar City District, Utah

Education. B.S. Forest Recreation U.S.U. 1974
B.S. Range-Watershed Management U.S.U. 1979

Experience. June to September' 73 and June to '74 Interpretative Naturalist Flaming Gorge National Recreation Area, Utah.

March to December '75, Crew Boss Inter Regional Fire Crew Gila National Forest, New Mexico.

April to July '76, Range Technician, Phase 1 Watershed Inventory, Moab District, Utah

July '76 to March '77 Park Ranger Utah Division of Parks and Recreation.

April to November '77 Phase 1 Watershed Inventory, Moab District, Utah.

June to September '78 Crew Boss Helitack Crew, Salmon, Idaho.

January to April '79 Hydrologic Technician U.S.F.S. Intermountain Forest and Range Experiment Station Logan, Utah. I worked hydrologic studies of Mine spoil areas near Soda Spring, Idaho.

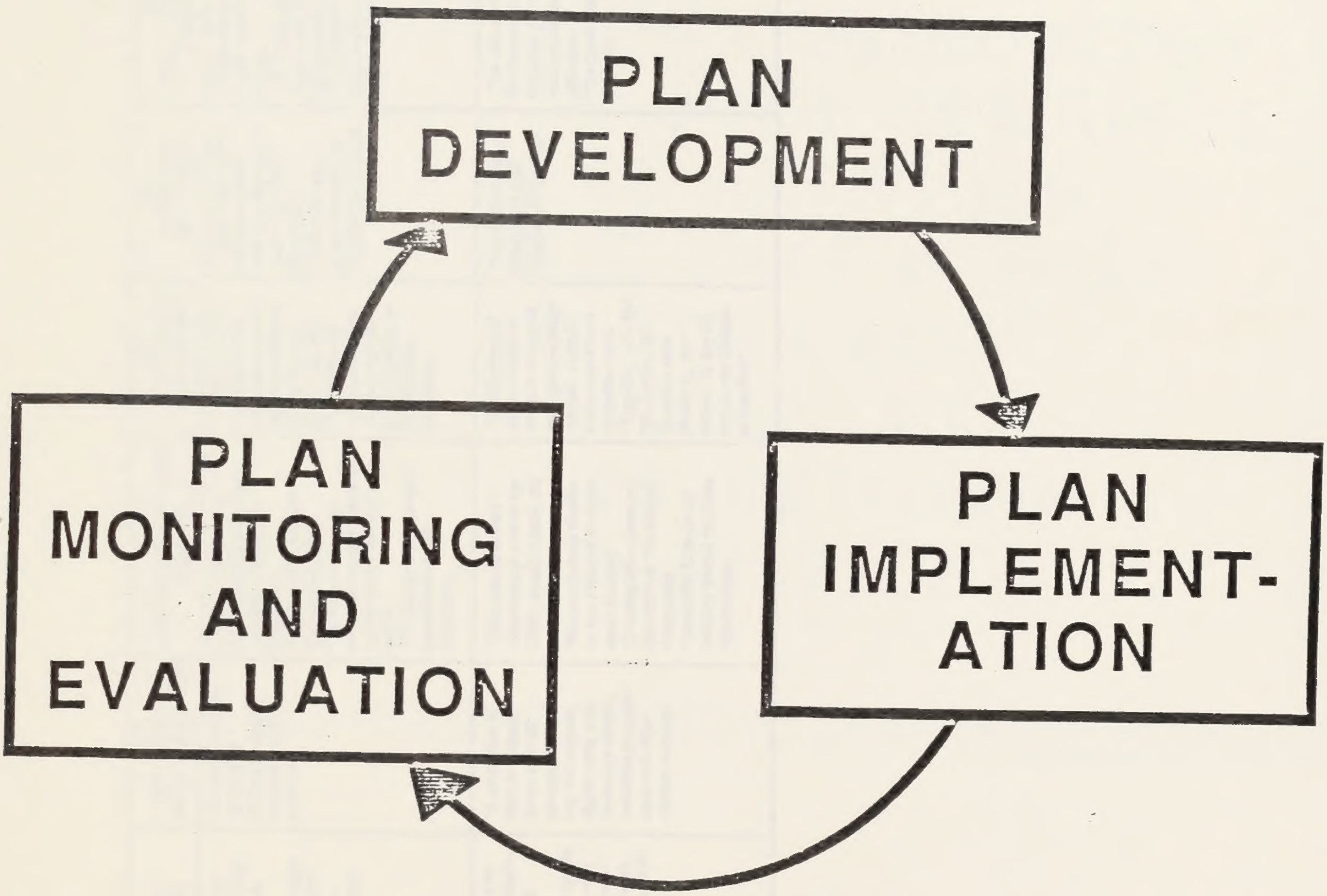
April '79 to October '80 Hydrologist on the Bureau's Rainfall Simulation Research Project, Denver Service Center. The study attempted to quantify grazing impacts on infiltration, runoff and sediment yield. Studies conducted in Canon City and Montrose Districts, Colorado; Lewistown District, Montana; Phoenix District Arizona and in conjunction with Utah State University, Logan Utah.

October '80 to December '82 Hydrologist Planning and Environmental Coordination Staff Cedar City District, Utah. Responsible for S-W-A input to EIS' and EAs.

December '82 to Present District Hydrologist Cedar City, Utah. Responsibilities include, Water Rights, Water Quality, Program leader S-W-A and S-W-A input for major EAs and EIS'. Worked on Watershed Activity Planning Manual and Handbook Washington Office Work Group.

#1

THE PLANNING CYCLE



SUMMARY OF BLM PLANNING PROCESS

PROCESS PHASE	PREPLANNING	NOTICE OF INTENT	(1) ISSUE IDENTIFICATION	(2) PLANNING CRITERIA	(3) INVENTORY AND DATA COLLECTION	(4) MANAGEMENT SITUATION ANALYSIS	(5) ALTERNATIVE FORMULATION	(6) ESTIMATION OF EFFECTS	(7) SELECT PREFERRED ALTERNATIVE	(8) SELECTION OF THE RESOURCE MGMT. PLAN	(9) MONITORING AND EVALUTION
PURPOSE	•To establish a commitment to the project at all levels within BLM. •To scope out the key elements of project management	•To get started. •To seek public involvement.	•To orient the process on problems/ multiple-use conflicts to be addressed indetail. •To focus attention on the critical trade-offs. •to ask the questions that must be answered.	•To provide sideboards/constraints on issues to be addressed. •To guide development of the RMP. •To define the scope of analysis.	•To provide essential facts for making analysis, evaluations, and decisions.	•To describe existing environmental elements and socio-economic conditions. •To describe current BLM management. •To determine ability of public lands to respond to the issues and concerns. •To identify management opportunities and limitations.	•To portray a mix of multiple uses and actions which could resolve the issues and address concerns. •To identify full range of options. •To provide different answers to the planning questions.	•To describe potential impacts and changes that would occur with each alternative. •To identify ways to avoid or miligate the adverse impacts.	•To identify which alternative best resolves the issues. •To clearly explain the course of action BLM proposes to take. •To provide the opportunity for public review and comment.	•To select the proposed RMP and approve it considering public review and comment. •To document the decision.	•To track implementation of action plan decisions. •To help keep the RMP current. •To determine if implementation is successful in meeting RMP objectives. •To assess whether the RMP continues to reflect the best resource management decisions.
PRODUCTS	•A "contract" or Preplanning Analysis that includes project support requirements, public participation plan, schedules, team make-up, budget and training needs, etc.	•A Fed. Register Notice. •Media announcements. •Letters to mailing list.	•A clear statement of a manageable number of significant issues for internal tracking, review, and inclusion in the RMP.	•A complete list for use by interdisicplinary team during process. •A summary for public review (usually with the issues in newsletter or other form), and inclusion in RMP.	•A collection of data in various forms from all sources: old planning documents, digital data, new inventory results, resource program data and other source material.	•This may be a shelf document or part of the RMP; usually 3 parts are included. •Resource Area Profile or the Affected Environment Chapter. •Existing Management Situation or "No Action" Alternative •Capability Analysis as building blocks for other Alternatives.	•Descriptions of several comprehensive resource management alternatives, each of which could be a complete plan. •Together with the "No Action" Alternative (see phase 4), this mahes up the alternatives Chapter of the RMP.	•The Environmental Consequences Chapter of the RMP.	•The description of the Preferred Alternative and the rationals for its selection. •The Draft RMP/ Draft EIS.	•The Proposed RMP/ Final EIS. Record of public comment, Governor's review, protests and responses. •The Approved RMP and Record of Decision.	•A monitoring plan that describes the standards, methods and intervals for monitoring and evaluating the RMP. •The documented results of monitoring including the data and analysis leading to any decision to modify the RMP through plan maintenance, admendment or preparation of a new plan.

#2

#3

PLANNING ISSUES

"A MATTER OF CONTROVERSY OR DISPUTE OVER RESOURCE MANAGEMENT ACTIVITIES OR LAND USE THAT IS WELL DEFINED OR TOPICALLY DISCRETE AND ENTAILS ALTERNATIVES BETWEEN WHICH TO CHOOSE OR DECIDE."

#4

ISSUES vs CONCERNS

PLANNING ISSUES

A. HOW SHOULD FORAGE BE ALLOCATED?

B. HOW SHOULD WE PROTECT IDENTIFIED VALUES IN THE SPRING CREEK WSA?

C. ARE THERE LANDS THAT SHOULD BE CONSIDERED FOR DISPOAL?

MANAGEMENT CONCERNS

A. SHOULD BLM ENHANCE (T & E) HABITAT?

B. ARE WE TAKING ALL REASONABLE STEPS TO REDUCE CULTURAL RESOURCE VANDALISM?

C. WHAT AREAS SHOULD BE OPEN TO FIREWOOD COLLECTING?

EXISTING "VALID" DECISIONS

D. WITH EIS / REGARDLESS OF CONTROVERSY (COAL)

D. WITHOUT EIS / WITH CONTROVERSY (OIL & GAS)

E. WITHOUT EIS / NO CONTROVERSY (RIVER-RUNNING PROGRAM)

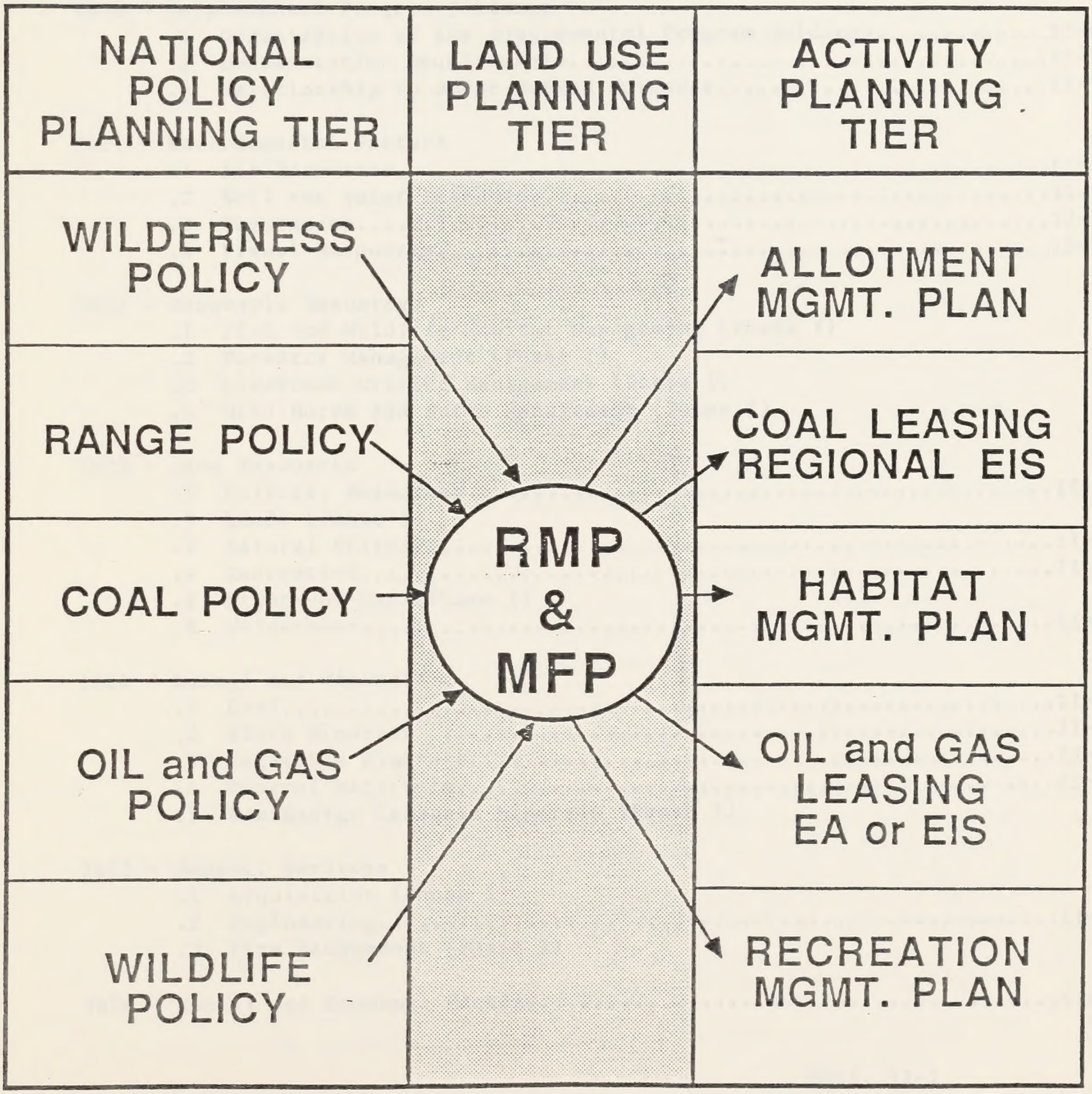
#5

ISSUES AND ALTERNATIVES

ISSUE OR CONERN	ALTERNATIVES			
	I	II	III	IV
A. FORAGE				
B. WSA				
C. DISPOSAL				
D. OIL & GAS				
A. T & E				
B. VANDALISM				
C. FIREWOOD				
D. COAL				
E. RIVER running				

#6

PLANNING INTEGRATES MULTIPLE PROGRAMS



1620 - SUPPLEMENTAL PROGRAM GUIDANCE

Table of Contents to the Draft Guidance for Phase II

DRAFT

.01 Purpose. This Manual Section describes the purpose, organization and use of the program activity guidance set forth in the 1620 series of the Planning Manual. It also describes the relationship between this guidance and other planning related guidance issued by the Bureau.

.02 Objectives. The 1620 series of the BLM Manual contains program activity guidance for the resource management planning process. It supplements the procedural and plan content guidance set forth in the 1600 and 1610 series of the Planning Manual. The overall objectives of the 1620 series are to:

A. Identify and clarify program activity requirements for resource management planning, where they exist.

B. Promote the development of a resource management planning base that in certain basic respects is comparable from one resource area to the next.

C. Provide Bureau personnel involved in the preparation of resource management plans with a readily available reference to program activity guidance that may pertain to their respective planning efforts.

D. Enhance the ability of Bureau managers and resource specialists to effectively participate in the interdisciplinary process used to prepare resource management plans and plan amendments.

E. Expedite District and State Office reviews of draft planning documents by establishing program specific standards for plan content.

.03 Authority. (See BLM Manual Section 1601.03.)

.04 Responsibility. (See BLM Manual Section 1601.04.)

.05 References. (See BLM Manual Section 1601.05.)

.06 Policy. The land use and resource management decisions, terms, conditions and other provisions of an approved resource management plan and its associated planning record must address all of the public land resources present in the area covered by the plan. Such specificity is essential to meeting the comprehensive land use planning requirements set forth in the Federal Land Policy and Management Act, the Federal Coal Leasing Amendments Act and the planning sections of the BLM Manual. (See, in particular, BLM Manual Sections 1602.22 and 1616.16 and the definition of a resource management plan at 1601.07.) Only with such specificity can an approved plan provide a planning base capable of supporting a broad range of subsequent resource management activities.

.07 Definitions. (See Glossary of Terms, BLM Manual Section 1601.07.)

.1 Organization of the Supplemental Program Guidance.

.11 Overall Structure. The 1620 series is organized by "program activity". These are the categories employed within the agency to organize and define resource management and resource management support activities such as wildlife habitat management, non-energy minerals leasing, or fire management. (See BLM Manual Section 1601.13 for a description of "program activity".)

.12 Format of the Individual Components. Each of the program activity components of the 1620 Series follows a standard format comprised of four sections. The purpose of each of these sections is described below. Additional program specific guidance (e.g. procedures, forms, etc.), if needed, will be placed in an appendix or handbook to the appropriate Manual Section of the 1620 series.

A. Determinations. This section describes the determinations or type of decisions that are required during resource management planning for the individual program activity. In every Resource Area in which the program activity is present, the land use planning determinations listed in this section must be either explicitly stated in the plan or derivable from the plan's multiple use prescriptions. This requirement applies regardless of whether the program activity is associated with an identified planning issue. (To further clarify these requirements, this section also describes those determinations that are normally made during subsequent activity planning. See BLM Manual Section 1601.12 for a discussion of the three tiers of the Bureau's planning system.)

B. Analysis. This section describes those factors that must be considered in making the determinations described in the preceding section. Generally speaking, these "factors" are activity specific considerations for which there is a specific statutory, regulatory, or court ordered documentation requirement. How these factors were considered during a planning effort must be clearly documented either in the plan itself or in its supporting record.

C. Information. This section outlines the type of activity specific information that is usually required by the manager and interdisciplinary team members during resource management planning.

D. Notices, Consultations, and Hearings. This section identifies program specific notice, consultation and hearing requirements, if any, that must be fulfilled during resource management planning. How these requirements were met must be clearly documented either in the plan itself or in its supporting documentation.

.13 Interdependence of the Components. The activity specific components of the 1620 Series are interrelated and interdependent. Thus, for example, if a particular planning area contains both fluid minerals and wildlife, one has to look at both the fluid minerals section (1624.2) and to the fish and wildlife management section (1622.1) to identify the decisions that must be made and the factors that must be considered.

.2 Documentation Requirements.

.21 General. The 1620 Series identifies a significant number of activity specific decisions that must be made during resource management planning. How these decisions are documented is expected to vary from plan to plan depending on the planning issues being addressed and on the manner in which the plan itself is formatted. In any given plan, some of these decisions may be portrayed in tables or on maps, others may be described in a general section devoted to on-going management practices; still others may be discussed in a discrete section of the plan or appendix to the plan that focuses on a particular geographic area or program activity.

.22 Applicability. All resource management plans and plan amendments initiated after the effective date of this guidance must comply with these requirements. Unless the Director grants a specific exemption, RMPs and plan amendments that have already been initiated must also comply with these requirements if the notice announcing the availability of the proposed plan or plan amendment is filed or published more than ninety days after the effective date of this guidance.

.3 Relationship to Other Bureau Guidance.

.31 Relationship to Other Planning Manual Sections. Resource management planning guidance that is not activity specific in nature is set forth in the Bureau's Planning Regulations (43 CFR Part 1600) and in BLM Manual Sections 1601 through 1619. The guidance set forth in the 1620 series of the BLM Manual is intended to supplement the Bureau's basic planning guidance and must be viewed from that perspective. (See BLM Manual Section 1601 for a description of the overall organization of the Bureau's planning Manuals.)

.32 Relationship to National and State Director's Policy Guidance. The 1620 series does not provide specific policy guidance on resource use priorities for the public lands. Such policy direction is regularly issued by the Bureau's Director and State Directors. The 1620 series has been designed to facilitate the incorporation of such guidance into ongoing and future planning efforts. The manner in which National and State level policy guidance is developed and incorporated into the Bureau's resource management planning system is described in Manual Section 1611.

.2 Soil and Water Resources.

.21 Determinations.

A. Resource Management Planning. The following soil and water-related determinations are made during resource management planning. These determinations must be either explicitly stated in the plan or derivable from the plan's multiple use prescriptions.

1. Management Objectives. Each RMP must establish soil and water management objectives. Individual objectives, either areawide or site-specific, may include but are not limited to:

a. Maintaining or increasing soil cover;

b. Maintaining soil productivity;

c. Controlling flood and sediment damage;

d. Meeting or exceeding established surface and groundwater quality standards;

e. Maintaining or improving riparian areas; and

f. Providing for physical and legal availability of water.

2. Management Direction. Each RMP must identify soil and water management actions necessary to achieve the management objectives. Such direction may include but are not limited to:

a. Establishing priorities for watershed or riparian area rehabilitation;

b. Identifying minimum surface and groundwater quality monitoring levels and locations;

c. Identifying any land use restrictions based on soil and water criteria;

d. Designating soil and water-related ACECs; and

e. Establishing a maintenance strategy for existing erosion or water-control structures and treatments (e.g., maintain indefinitely, stabilize and abandon, abandon).

B. Activity Planning. The following soil and water-related determinations are usually deferred to activity planning: specific resource objectives (e.g., vegetation cover target to control soil erosion), watershed or riparian rehabilitation techniques, monitoring techniques and schedules, and the design and placement of improvements. Whenever practical, such determinations are made during the preparation of resource activity plans (e.g., AMP, HMP, FMP) instead of preparing actual soil and water (or watershed) activity plans.

.22 Analysis. The planning record must clearly document the analyses that were conducted in arriving at the soil and water-related RMP determinations set forth above. Specific factors to be considered in conducting such analyses include:

A. Legal Requirements. The BLM has a number of statutory responsibilities that must be considered in establishing soil and water management objectives and actions. Such statutes include the Colorado River Salinity Control Act, the Safe Drinking Water Act, the Clean Water Act, the Public Rangelands Improvement Act, the Farmland Protection Policy Act, Executive Order 11988 on Floodplain Management, and Executive Order 11990 on the Protection of Wetlands. These and other applicable statutes are described in BLM Manual 7000 (Soil, Water, and Air Management).

B. Watershed Condition. The concept of watershed condition is described in BLM Manual 7210. The process for determining watershed condition includes stratifying the planning area into appropriate hydrologic sub-units and selecting and evaluating pertinent watershed components (see .23A1).

C. Watershed Vulnerability. Watershed vulnerability is an expression of the susceptibility of a watershed unit to degrade from the current condition.

D. Watershed Responsiveness. Watershed responsiveness is an expression of the ability of a watershed unit to improve from the current condition through management or treatment measures.

E. Existing and Anticipated Demand for Water. A relationship between availability and demand should be established according to existing and projected water uses. Special management consideration should be given to overappropriated basins, instream flow requirements, and federally reserved water.

.23 Information.

A. Data Elements. The following soil and water-related data are usually required by the area manager and the interdisciplinary team during resource management planning.

1. Watershed Condition Component. The following components are assessed to determine watershed condition: soil erosion, sediment yield, water quality, and water quantity.

2. Water Availability. This element includes information on both the physical presence and legal availability of water.

3. Soil/Water Features. The principle features of interest include floodplains, prime and unique farmlands, soils of statewide importance, riparian areas, municipal watersheds, non-point source (208) water quality planning areas, NPDES permit sites, and polluted groundwater systems.

4. Soil/Water Improvements. This element includes the location, maintenance history, and performance assessment for existing erosion and water-control structures or treatments.

B. Data Sources. Principle soil and water data sources include soil surveys, ecological site descriptions, reservoir sedimentation studies, water quality monitoring records, streamflow records, well logs, water source inventories, project files, and State water rights files. In addition, there are several existing formulas and models which can aid in characterizing the data elements.

.24 Notices, Consultations, and Hearings. Consultation and coordination with other Federal, State, and local agencies are required as directed by the Watershed Protection and Flood Control Act, the Clean Water Act, and OMB Circular A-81 (see BLM Manual 7000.)

I. Activity Planning Process

A. Pre-Planning Analysis
B. Inventory
C. RMP/MFP
D. Activity Planning
E. Implementation
F. Monitoring/Evaluation

II. Activity Planning Philosophy

A. Intent of Plan is to solve soil-water problems
B. Directly involves manager in process
   1. Identifies scope of plan
   2. Identifies target areas
   3. Designates core team
   4. Works with team to develop objectives
   5. Works with team to develop actions
   6. Is responsible for plan implementation

C. Activity plan functions
   1. Problem identification and analysis
   2. Proposes problem solutions
   3. Creates on the ground actions
   4. Monitors - evaluates actions
   5. Provides vehicle to request funding through AWP Process

III. What type of activity plan should be used

A. Site specific
   1. Nature of problem
   2. Extent of problem

B. When a new activity plan is needed
   1. Soil-water problems are beyond scope existing activity plan

C. Use of watershed management plan
   1. Soil-water problems beyond scope of any other activity plans

D. Coordinated activity plan
   1. Soil-water problems can be addressed in plan
   2. Decision document

IV. Required activity plan elements

A. Elements required in watershed Management Plan
   1. Management summary
   2. Detailed site description
   3. Problem identification and analysis
   4. Objectives
   5. Map
   6. Alternatives
   7. Economic analysis
   8. Risk analysis

9. Environmental and cultural clearances
10. Monitoring/evaluation plan
11. Maintenance needs and costs
12. Project schedule
13. Project budget
14. Appendix
15. Environmental assessment

B. Soil-water elements necessary to be included in other activity plans and those required by Bureau Manual 1619 (Activity Plan Coordination).
   1. Site description
   2. Problem Identification and analysis
   3. Current resource management
   4. Public interest
   5. Objectives
   6. Constraints
   7. Alternatives
   8. Preferred alternative selection
   9. Monitoring/evaluation plan
   10. Maintenance needs and costs
   11. Project schedule
   12. Project budget
   13. Environmental assessment

V. <u>Activity Plan Example</u>

A. Round Valley

Planning - Implementation Process

Pre-Plan Analysis

1. Identify needed resource information. To be inventoried
2. Identify time and money needed for inventory

↓

Inventory

1. Collect resource information

↓

RMP

1. Analyze inventory data
2. Provide objectives and policy for each resource program
3. Prioritize watershed problem areas
4. Identify areas for further inventory or activity planning
5. Provides basis for funding request for further inventory or WAP.

↓

Activity planning

1. Site specific analysis of identified areas from RMP
2. Thorough problem identification and analysis
3. Process and implement actions to solve problem and symptoms of S-W
4. Provides detailed monitoring plan

↓

Implementation

1. Management changes
2. Structural and/or land treatments

↓

Monitoring/Evaluation

1. Monitor actions for fixed period of time
2. Evaluate monitoring data
3. Update activity plan and/or RMP if objectives are not being met or are not appropriate.

I. Activity Planning Philosophy

A. Purpose of soil-water Planning

1. To protect, maintain, or improve soil and water resources associated with public lands, by:

   a. Preventing deterioration of watershed conditions where technically and economically feasible.

   b. Rehabilitating areas where runoff and accelerated erosion have resulted in unacceptable resource conditions.

2. To prevent or minimize the threat to public health and safety or economic losses due to floods, sedimentation, or decreased water quality.

3. To provide a systematic process for:

   a. Identifying and quantifying and site-specific watershed problems.

   b. Identifying actions to solve problems.

   c. Monitoring progress towards established watershed project objectives.

   d. Focusing funds and personnel on project-level activities.

B. Directly Involves Area/District Manager

1. Works with soil-water specialists to determine target areas and scope for Activity Plan effort.

2. Designates interdisciplinary core team to work on plan.

3. Makes money and personnel commitments for planning effort through AWP process.

4. Works with team to develop objectives.

5. Works with team to develop actions to solve problems.

6. Works with team in presenting plan to affected public parties

7. Is responsible for implementation monitoring and adjustment of planned actions.

C. Activity Plan Functions

1. Problem identification and analysis
Once problems have been identified and analyzed actions can be proposed to solve problems and not just symptoms.

2. Proposes solutions
Solutions are derived to solve identified soil-water problems.

3. Initiates on the ground actions
Proposed actions are translated to on the ground projects. Problems are actually solved.

4. Monitors-evaluates actions
All actions are monitored on a regular basis to see if objectives are being met. Adjust plan objectives or actions to better solve soil-water problems.

5. Provides vehicle to request Funding through AWP process
Bureau policy requires soil-water actions be analyzed in an activity plan before they can be funded.

III. <u>What type of Activity Plan Should Be Used</u>

A. Site Specific

1. Nature and extent of problem
Problem needs to have a preliminary analysis to determine the best type of activity plan to be used.

B. When is a New Plan Needed

1. Soil-Water Problem is Beyond Scope of Existing Plan
The use of an existing plan can be valuable especially if it is managing the resource that is the cause of the problem (ie. grazing, timber harvesting or mining). This way decisions can be made to take actions to solve the problem.

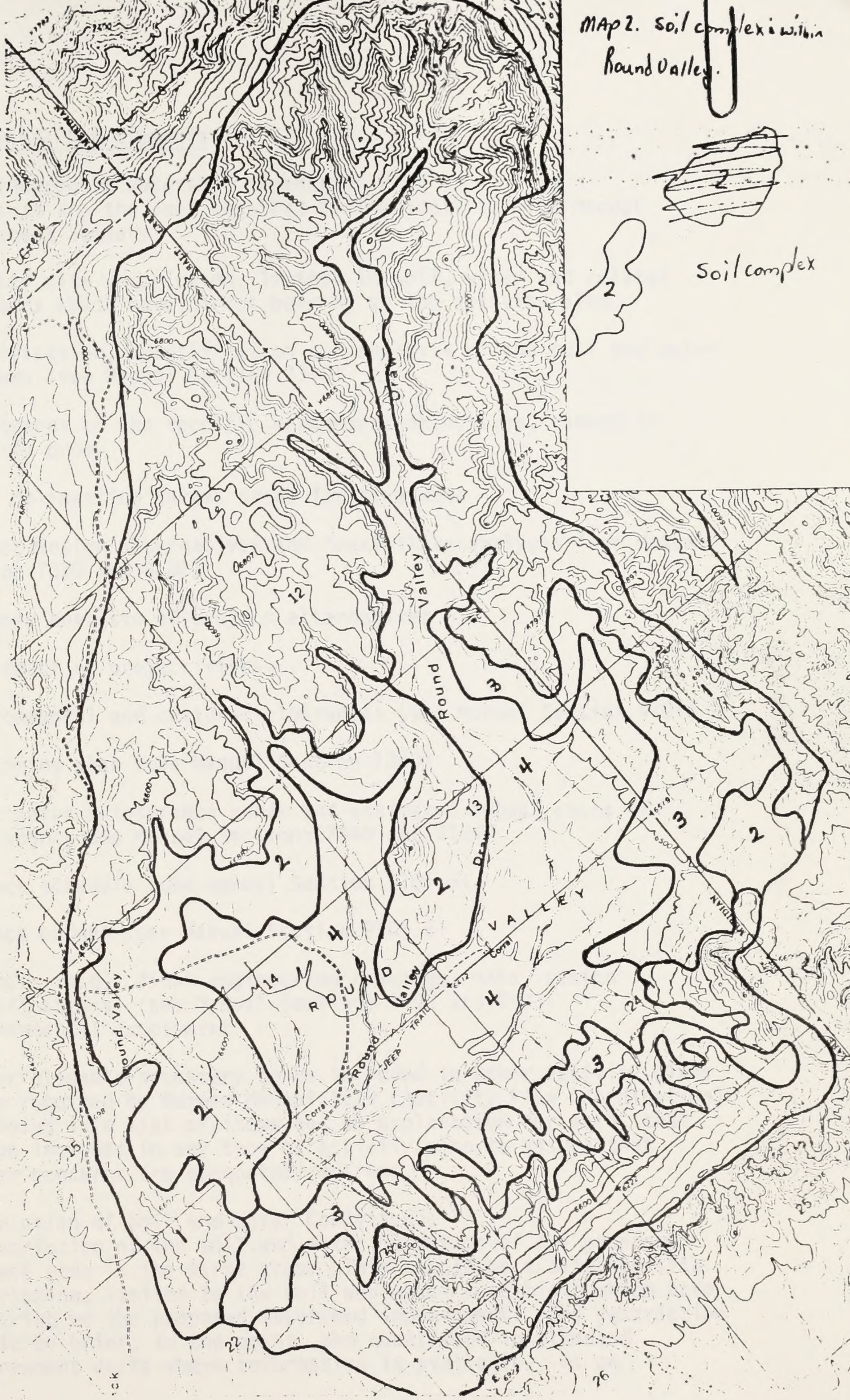
C. Use of Watershed Management Plan

1. Soil-Water problems are beyond the scope of any other activity plan
This type of plan should be used when soil-water problems occur on a large scale causing an unrealistic situation where other resource values cannot be addressed. The test maybe, "are the soil-water problems affecting other resources or are the other resource causing soil-water problems"?

D. Coordinated Activity Plan

1. Soil-Water Problems can be Addressed in Plan
This the plan that should be used. This is dependent on if management is willing to make the plan boundaries large enough to address the soil-water problems. This may require that watershed boundaries be used instead of say an allotment boundary. This case may in fact have several or one allotment within the plan boundary.

2. Decision Document
By using the Coordinated approach, the plan will provide the power to make decisions on the uses of an area that are causing the problem. For example, the plan would include all the management prescriptions to solve grazing problems.


MAp 2. Soil complex within Round Valley.
Soil complex
Round Valley
Draw
ROUND VALLEY
JEEP TRAIL
Corral

IV. Required Activity Plan Elements

A. Elements Required in Watershed Management Plan

These elements are the ones required by the activity Plan Manual

1. Management Summary
2. Detailed site description, limited to soil, water and related variables which have direct bearing on the activity plan
3. Identification, quantification and analysis of the soil and water problems (see Manual Section 7310)
4. A statement of the specific management objectives, ranked in priority order
5. A map delineating target areas for treatment
6. Project design alternatives and feasibility analysis (see Manual Section 7330 and 9102)
7. Economic analysis of project alternatives
8. Assessment of project risks
9. Environmental and cultural clearances (see Manual Section 9101)
10. Monitoring plan (see Manual Section 7340)
11. Anticipated maintenance needs and estimated annual costs of maintenance see Manual Sections 7340 and 9104)
12. Project schedule (see manual Section 9101.5)
13. Project budget (see Manual Section 9101.6)
14. Appendix (e.g., final engineering drawings, maps, design specifications) (see Manual Sections 9102 and 9103)
15. Environmental assessment

B. Soil-Water elements necessary to be included in other activity plans and those required by Bureau Manual 1619 (Activity Plan Coordination) The following is a list of items and an explanation for each, that need to be included in any type of activity plan to assure that soil-water concerns are adequately address.

1. Description of Soil and Water Condition
A description of the soil and water condition of the proposed project area is the first step. This should be a detailed site description, limited to the soil and water conditions which have a bearing on the proposed watershed improvement. The description should be brief, to the point, and quantified in standard measurement units where information is available. As an

example, the description of the water resources could include the identification of water quality variables quantified as specific as information will allow, estimates of sediment yields (ton/acre) if applicable, estimated water yields, watershed relief or a description of the ground water resources. State water quality standards, and USGS professional papers/water supply papers can be incorporated by reference.

2. Problem Identification and Analysis
A watershed problem is defined in Manual Section 7320 to be a soil or water resource condition which is presently unacceptable to management, or an opportunity to develop or enhance the soil or water resource. The problem siltation must be quantified by field measurements and stated in terms which will allow for both selection of treatments and post-treatment monitoring. A description of the unsatisfactory watershed components (problem quantification) stated in terms of that specific watershed component is required. A general statement such as "erosion is a problem in watershed X," should have been identified in the RMP or MFP and is too general for activity planning purposes. The problem must be quantified such as "an erosion rate of 6 tons/acre in watershed X is excessive and requires a 50% reduction". If specific numerical quantifications are not available, the problem should be broken down as specific as possible. If sediment yield is a problem, the precise source of that sediment should be identified.
One approach to problem quantification is through the use of evaluation parameters. The watershed component in the problem area. This would allow the manager to envision where the problem area is located in respect to the other extreme conditions, and provide him with a qualitative estimate of resource conditions. Such an evaluation system is useful in areas where a specific standard, such as state water quality standards, are available. The state standard provides the evaluation criteria as the where the stream sediment should be in relationship to current uses. Once the problem has been identified and quantified, a diagnosis or determination of the cause must be completed. This is an extremely important part of the activity plan with the purpose being to avoid the mistake of treating the symptoms instead of causes. Treating symptoms results in temporary solutions and constant maintenance. Treating the cause will result in accomplishing long-term objectives.

3. Current Resource Management and Existing Data Base
The watershed improvement project must be compatible with current resource management. Most conflicts should be resolved in the RMP, but some my exist when specific site locations have been identified. Coordination with other activities must be done. This is on of the advantages of utilizing an existing AMP, HMP, or other activity plans.

4. Public interest
Public interests and desires concerning a particular watershed project need to be addressed. Local entities should be coordinated with for information and ideas.

5. Objectives
The objectives of the watershed activity are based upon what management wants to accomplish with the watershed project. These are often derived from RMPs or MFPs. The objectives are the basis for the activity plan and must be stated in terms that can be measured in the same units as used for problem quantification. Quantification of the objectives is the basis for monitoring. If multiple objectives are to be met, they should be assigned a priority ranking, with the more important objectives being completed first.

6. Constraints
These are the restrictions on the proposed watershed project designed to protect other values. Major constraints should have been identified in the RMP, or MFP. Besides conflicts with other resources, constraints can be either physical, legislative, economic, or political. Physical constraints can be topographic or climatic. Wilderness designations are an example of a legislative constraint, and wishes of local governments and community groups are examples of political constraints. Time is also a constraint on activity planning. If activity planning is not done in a timely manner and results in delays in project implementation, management may lose interest in the effort. Because the purpose of activity planning is to improve watershed condition, not writing watershed plans, only about 10 percent of the programmed work months and funds should be utilized in watershed activity plan preparation. The remaining 90 percent should be used for project design and implementation.

7. Alternatives
Prior to selecting target areas and watershed treatments, several project alternatives should be arrayed and analyzed for management's review and selection of a preferred alternative. All alternatives considered should be capable, with a high degree of probability, of achieving the management objectives. Non-structural (land-use management) as well as structural alternatives should be included. Each of the alternatives should be analyzed using the following criteria:

   a. Technical feasibility
   b. Benefits to be derived
   c. Hydrologic risk
   d. Projected maintenance needs
   e. Cost effectiveness

   Technical feasibility should be reviewed by a soil scientist, hydrologist, and other affected resource specialists. If structural treatments are proposed, the alternatives should be reviewed by an engineer. It is highly recommended that an outside technical review be done by someone not directly involved in the activity plan.
   All possible on-site and off-site resources and socioeconomic benefits should be tallied and, wherever possible, quantified for each alternative.
   An assessment of hydrologic risk should be done for each alternative. This will be used for determining project costs

C. Objectives

The objectives of the watershed activity are based upon what [illegible] expected to be accomplished with the watershed project. These [illegible]. The objectives are the basis for the activity plan and must be stated in terms that can be measured [illegible] as used for [illegible].

Quantification. The quantification of the objectives is the basis for monitoring. If conflicts [illegible] objectives are to be met, they should be assigned a priority ranking, with the more important objectives being accomplished first.

D. Constraints

Constraints to implementation of the proposed watershed project [illegible]. Major constraints should [illegible] identified [illegible] possible conflicts with other resources, and [illegible] such as extreme physical, legislative, economic, or political. Physical constraints [illegible]. Wilderness [illegible] are examples of [illegible]. Time is also a constraint in activity planning. If activity planning is [illegible] the remaining [illegible], [illegible] only about 75 percent [illegible]. The remaining 25 percent should be used for [illegible].

E. Alternatives

[illegible]

a. [illegible]
b. [illegible]
c. [illegible]
d. [illegible]
e. [illegible]

[illegible]

and for project design specifications. BLM Technical Note 337 should be consulted for risk analysis procedures.
For the alternatives which involve structural treatments, maintenance needs should be forecasted for the life of the project. Maintenance costs should be included in the economic analysis of the alternatives.
All costs then are summed for each alternative. Because of the difficulty in placing monetary values on benefits derived from watershed improvement projects, and accurate benefit-cost analysis may be difficult if not impossible to perform. The recommended type of economic analysis is "cost effectiveness analysis." In this type of analysis, it is assumed the benefits will be equal for all alternatives. All costs are calculated on a present value basis. The preferred alternative, from an economic perspective, it the one with the lowest cost. Final selection of the preferred alternative is a management responsibility. The alternative recommended to management should (1) be technically feasible, (2) have a high probability of achieving the watershed improvement objectives, (3) have the lowest cost per unit of benefits, and (4) be acceptable to a majority of affected public land users.

8. Preferred Alternative Selection
The preferred alternative will include the following elements:

a. Reason(s) for selection of the preferred alternative
b. Selection of target areas for treatment
c. Maintenance schedule

9. Monitoring/Evaluation
This is the part of the activity plan where progress towards the stated objectives is measured. Based on the monitoring data, changes in the activity plan objectives or prescriptions can be proposed and implemented. Monitoring is the final and most important step in the Bureau planning process. Information gained from monitoring can be used to refine objectives and actions proposed in future activity planning efforts. Continued refinement of objectives and methods for problem solving will assure that on the ground projects have the best chance of success thus saving the Bureau money in the future.

10. Maintenance needs and costs
Maintenance cost should be based on past experience with the same types of projects that are being proposed. The Division of Operations normally keeps records of construction and maintenance costs for similar projects which will aid in determining this information for the activity plan.

11. Project schedule
A schedule for implementing the activity plan and completing projects should include all major subtasks, their planned completion date and person(s) responsible for completing the subtask.

12. Project budget
The actions and projects (with their respective costs) to be taken as a result of the plan should be listed in priority order. Once the order is established, the amount of the plan that can be implemented in any given year can be determined after AWP cost targets are received.

13. Environmental Assessment
The area Manager will determine the necessary environmental clearances and mitigations appropriate to the preferred project alternative and is responsible to see the Environmental Assessment is completed.

V. Activity Plan Example

A. Round Valley

I have included the following example to help show what I consider to be the driving force and value of an activity plan.

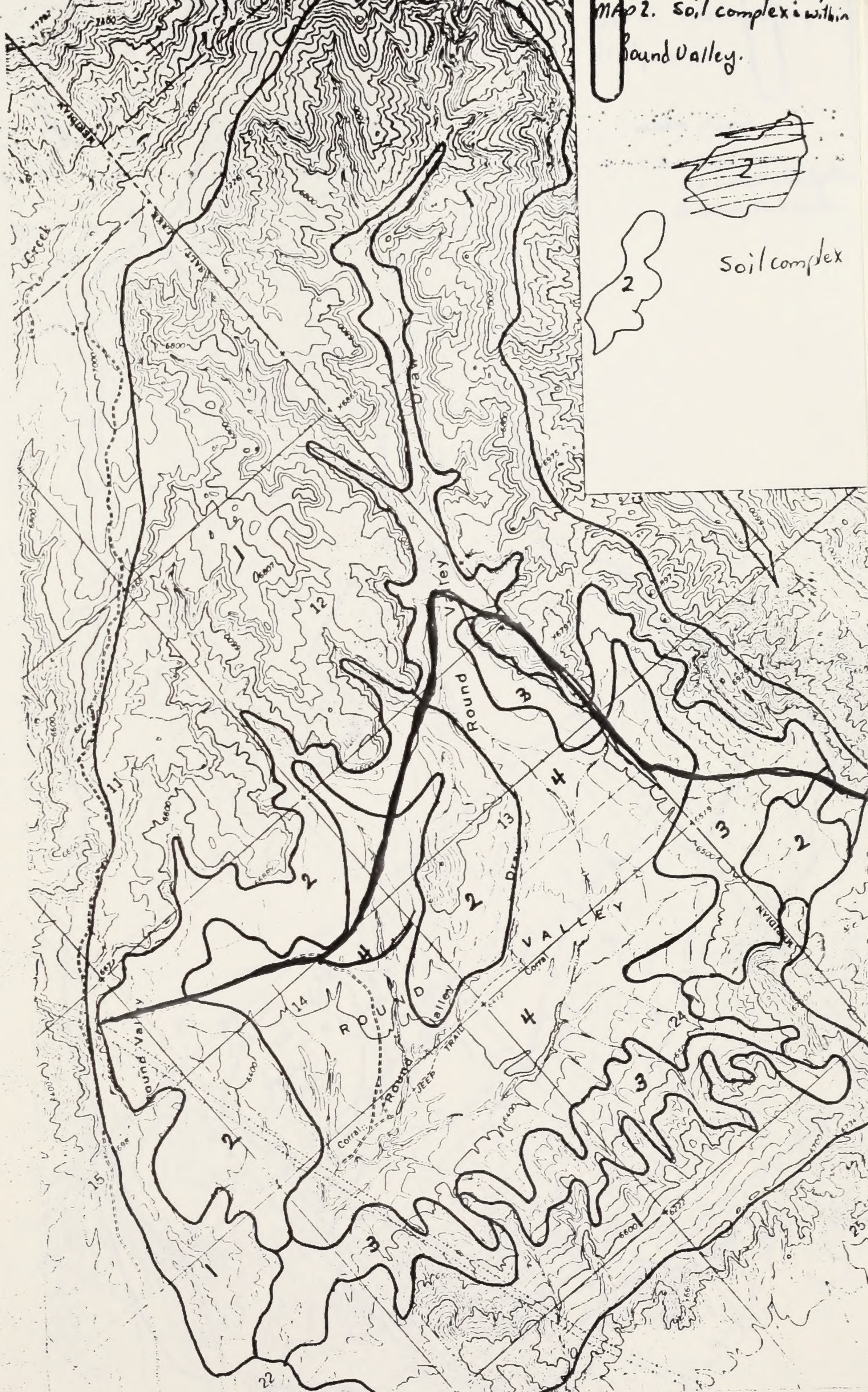
In this example all the data collection, problem identification and analysis, and economic analysis has been completed and the actions to be taken are those from the preferred alternative. The analysis has shown that the main problem within the basin is mostly historic grazing uses and current heavy grazing use of the bottom lands which is particularly harmful to soil area 2. Soil area 2 is producing large amounts of runoff and sediment to the actively eroding gully system.

The eastern half of the basin occurs within the Mud Springs WSA which places a constraint on the implementation of many desired management actions. The only action(s) that can be taken within the WSA are those that can be shown to be non-imparing to wilderness values. An IMP analysis has shown that construction of 2 miles of fence will not impair wilderness values.

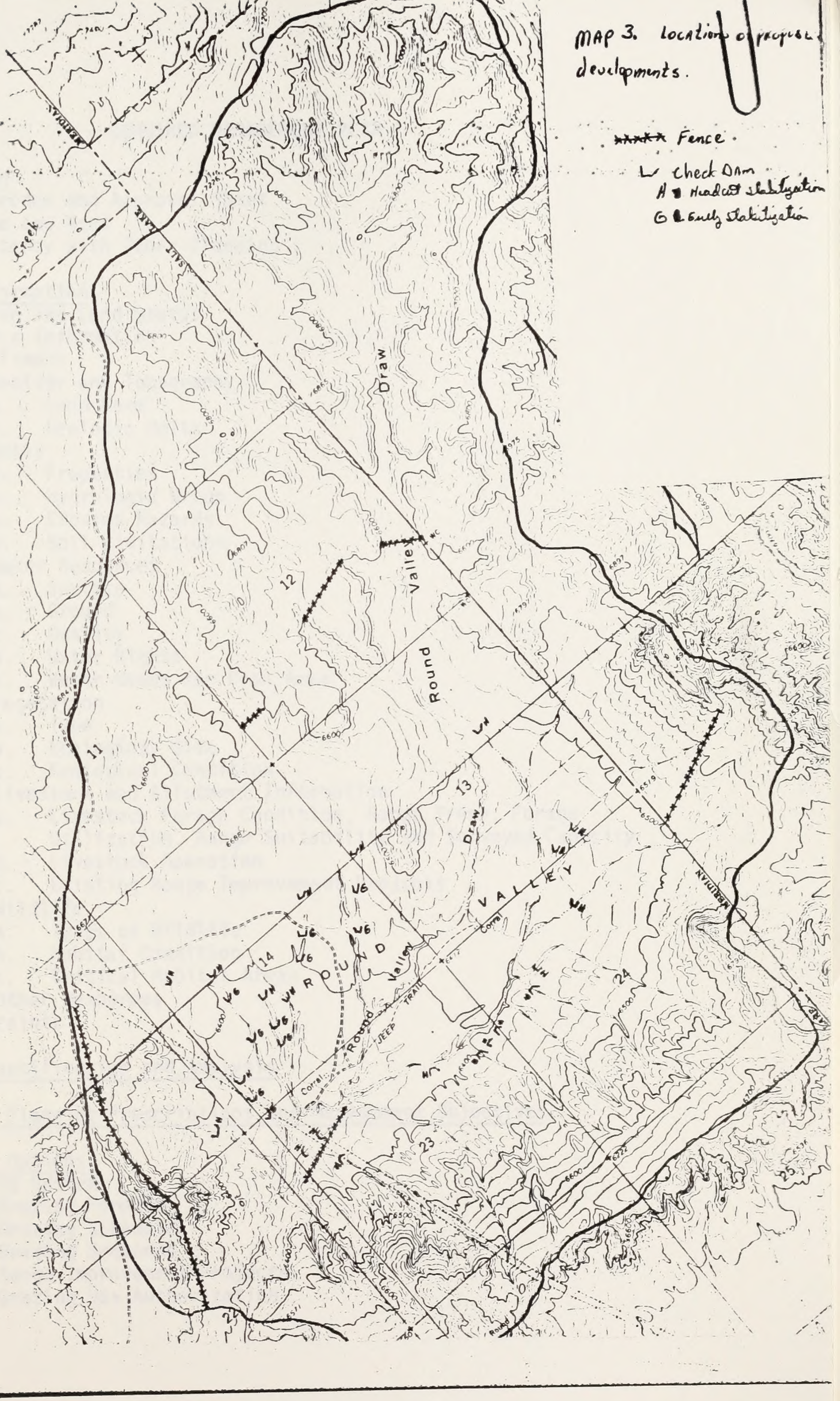
The list that follows shows how I have approached the problem.

Objective 1.	Reduce sediment yield from soil complex 2 from the current estimated rate of 2.06 tons/acre/year to 1.03 tons/acre/year within 10 years.
Objective 2.	Increase ground cover from the current 35% to 55% in 10 years. This is necessary to protect the soil surface from raindrop impact.
Action 1.	Build 2 miles of fence that are necessary to implement a 3 pasture deferred rotation grazing system.
Action 2.	Reduce livestock numbers by the allowable amount based on Bureau and District policy. Continue to adjust livestock numbers to bring them into line with carrying capacity as determined by range monitoring studies.
Monitoring	Establish 2 paired runoff plots to measure soil loss on soil 2. Two plots will be fenced to exclude grazing so "natural" soil loss can be measured. The other two plots will continue to be grazed. Read soil and runoff each year on September 25. Establish 5 ground cover transects on soil complex 2. Measure ground cover at each transect on September 25.
Objective 3.	Reduce sediment yield from the gully system from 2622 tons/year to 1106 tons/year within 10 years.
Action 3.	Build 20 check dams to stabilize and control headcutting and widening of the actively eroding gully system.

monitoring	Place permenant markers at all current headcut locations. Read headcut migration from these fixed points each year on September 25. Place a marked fence post in upstream side of each check dam to measure sediment deposition. Read annually on September 25.
Evaluation	Evaluation will be done each year immediately following data collection. Any adjustments to the plan or actions needed will be authorized by the Area/District Manger. Final Evaluation of the plan will be made in 10 years.


MAP 2. Soil complexes within Round Valley.
Soil complex
Round Valley
ROUND VALLEY
Round Valley Draw
JEEP TRAIL
Corral
Creek

MAP 3. Location of propose developments.



COMBINED MANAGEMENT PLAN

I. Introduction
  A. Concurrence and Approval Sheet
  B. Purpose and Need
  C. Consistency with Other Planning

II. General Information
  A. Location and Land Status
  B. Resource Information
    1. Climate
    2. Geology and Topography
      a. Land Form
      b. Geologic Units
    3. Soils
      a. Properties
      b. Hydrologic Group
      c. Erosion Hazards
      d. Soil Limitations
    4. Water Resources
      a. Surface
      b. Ground
      c. Quality
      d. Water Rights
      e. Water Needs for Plan Area
    5. Vegetation
      a. Type
      b. Ecological Site
      c. Ecological Condition
    6. Livestock and Allotment Information
      a. Livestock Forage Condition, Range Trend, Forage Utilization, Range Suitability and Surveyed Capacity
      b. Livestock Operation
      c. Existing Range Improvement Projects
    7. Wildlife
      a. Types of Wildlife
      b. Habitat Condition
      c. Critical Habitat Areas
    8. Other Resources
  C. Constraints

III. Problem Identification and Analysis

IV. RMP or MFP Planning Prescriptions and Management Objectives

V. Managerial Options
  A. Grazing System
    1. Grazing Formula
    2. Grazing Schedule
    3. Grazing Sequence
    4. Range Improvement Projects
    5. Grazing Use Authorization

B. Watershed Improvement Projects
   1. Map Showing Projects
   2. Project Priority List
   3. Costs
C. Wildlife Habitat Improvement Projects
D. Alternative Cost and Economic Analysis

VI. Preferred Alternative Selection
   A. Prioritization of Actions
   B. Funding Responsibilities and Commitments

VII. Coordination with Other Programs
   A. Review by Specialists

VIII. Monitoring Studies and Evaluation
   A. Livestock Grazing
      1. Standards
      2. Methods
      3. Intervals
   B. Watershed
      1. Standards
      2. Methods
      3. Intervals
   C. Wildlife
      1. Standards
      2. Methods
      3. Intervals
   D. Plan Evaluation
      1. Standards
      2. Methods
      3. Intervals

IX. Implementation Schedule

X. Public Participation

XI. Management Agreement

XII. Environmental Analysis

I. Introduction

This section outlines the need for the planning effort. There are certainly problems or a plan would not be written on an area. This section should include a brief description of the consequences involved if the plan is not implemented.

Also this section should outline the consistency this plan has with other plans, such as, has the area been identified in the broad land use plan(EIS, RMP, URA-MFP) and is the proposed plan consistent with any other activity plans written on the area.

II. General Information

Information included in this section outlines the existing resources condition much the same way as an EIS or EA does.

The constraint portion needs to outline all resource, physical and/or political problems that could present difficulties in implementing the plan.

III. Problem Identification and Analysis

All problems in the area that have lead to resource degradation need to be identified and analyzed. This is important so the plan proposes to solve the problem and not just the symptoms. A good analysis of the problems will also help to assure that the same things that caused the resources to degrade do not occur again.

IV. Management Objectives

This section ties directly to the problem analysis section. Objectives should be written to solve each identified problem. The objectives need to be quantifiable, site-specific and realistic (ie increase wildlife forage by 200 lbs/acre/year or reduce sediment yield by 1 ton/acre/year). This is necessary because the monitoring plan will be written to compare the on the ground actions against what is happening on the ground to determining if the objectives are being meet.

V. Alternative Identification and Analysis

Alternatives should be identified that will meet the objectives. These alternatives should present a number of ways to solve the resource problems that have been identified. The alternatives identify ways that the resource values can be improved through time regardless of budget allocations. Current realities require that we address problems with reduced funds. The alternative chosen as the preferred, will likely have a large expenditure of funds. If the preferred alternative was the only way of meeting the objectives, the plan in essence becomes useless in meeting the objectives. Inclusion of objectives allows the Bureau to address the problem at any level depending on funding.

A benefit cost analysis must be included for each alternative. This information can then be used in determining which alternative would be chosen as the preferred.

VI. Preferred Alternative Selection

This section provides a brief discussion of the preferred alternative and why this was the alternative chosen.

VII. Coordination with Other Programs

This section would be used for coordination purposes. It is not only important to assure the proposed actions are not presenting unacceptable problems to other resources but the other programs could provide unique and cost effective ways in meeting the objectives.

VIII. Monitoring Studies and Evaluation

A monitoring plan would be written to evaluate all actions to determine progress towards meeting the outlined objectives. The plan would include quantifiable studies(transects, photo points ect.) that would be used as the "yard stick" to measure progress. The plan provides the information to change action, change objectives and/or include new actions.

IX. Implementation Schedule

This section outlines the priorities to be taken in implementing all on the ground actions. It also lists program and funding(or mixture of funds) all programs will be responsible for. Actions would be placed in priority order for implementation. Following is an example of the process. Four sediment retention structures will be constructed in year 1 of plan implementation. Costs of the project will be shared equally between Soil-Water-Air, Range and Wildlife.

X. Public Participation

This section contains information regarding the amount of public coordination that has taken place in producing the plan. The level and amount of public participation should be commensurate with the sensitivity of the area and the proposed actions. For example, an area of heavy grazing and threatened or endangered plants or animals should be coordinated with the permittees, Fish and Wildlife Service and possibly the Congressional Delegation.

XI. Management Agreement

This section outlines the portion of the plan the permittee, the Bureau and any other public interest group is responsible for. Responsibilities would be clearly spelled out to prevent confussion.

BUREAU OF LAND MANAGEMENT
WATERSHED ACTIVITY PLAN IMPLEMENTATION
AND PROJECT PLANNING CHECKLIST

District ______________________ Resource Area ______________________

Project Name ____

Project Leader ______________________ Target FY for Completion ____________

Project Location ____

____

WORK TASKS	PERSON RESPONSIBLE	PLANNED COMPLETION DATE	ACTUAL COMPLETION DATE	INITIAL
1. Project(s) proposed to Area Manager and approved for further planning.				
2. Final management objectives defined.				
3. Target areas delineated.				
4. Project map(s) prepared.				
5. Project file prepared and JDR number assigned.				
6. Show-me-tour with Area Manager, appropriate resource specialists, operations staff, permittee(s), and other affected agencies.				
7. Initiate and prepare draft of needed cooperative agreements.				
8. Area Manager reviews and resolves any conflicts; if conflicts area irreconcileable, terminates project.				
9. On-site feasiblity studies conducted; specific project locations flagged.				

WORK TASKS	PERSON RESPONSIBLE	PLANNED COMPLETION DATE	ACTUAL COMPLETION DATE	INITIAL
10. Archaeological clearances obtained; easements and rights-of-way acquired as necessary.				
11. Hydrologic and soils analysis completed for project design.				
12. Engineering designs completed.				
13. Prepare cost estimates.				
14. Final field survey and design completed.				
15. AWP information prepared.				
16. Projects approved by DM for inclusion in AWP.				
17. Requisitions for contracting and materials submitted.				
18. Contract bids solicited.				
19. Materials ordered.				
20. Personnel scheduled.				
21. Show-me-tour.				
22. Contract award.				
23. File notice of interest to construct.				
24. Contract administration and final acceptance.				
25. Monitoring plan initiated.				
26. Project completed.				
27. JDR completion and submission.				

SOIL INTERPRETATIONS

Course: 7000.1
Instructor: Volk

RESOURCE MANAGEMENT THROUGH SOIL INTERPRETATIONS

Prerequisites: Knowledge of National Soils Handbook (NSH), Soil Survey Manual (SSM), National Cooperative Soil Survey (NCSS), Bureau of Land Management Soil Manual 7000 and 7100

Objectives:

1. To be able to provide soil interpretations to other disciplines and management from data sources, such as published soil surveys and soils form 5

2. To be able to initiate, test, coordinate, and prepare interpretations where none exist for resource management

Topic Outline:

1. Interpretation

    a. Definitions
    b. Purpose of Interpretations
    c. Soil Limitation Ratings
    d. Soil Suitability Ratings
    e. Technical Guides
    f. Soil Potential Guides

2. Interpretations from a Soil Survey

    a. Published Soil Survey
    b. Unpublished Soil Survey Information

3. Interpretations from "Scratch"

4. Summary

Resume:

William P. Volk

Certified Professional Soil Scientist $1546

by American Registry of Certified Professionals
in Agronomy, Crops, and Soils, Ltd.

(ARCPACS)

Education:

BS in Ag. Production	1972	Montana State University
MS in Soils	1974	Montana State University

Employment:

1966-1969	U.S. Army
1970-1974	Montana State
1974-1979	Soil Conservation Service - Soil Scientist
1979-present	BLM - Soil Scientist

Presently:
State Soil Scientist/Range Conservationist at Montana State Office, 932,
FTS 585-6655

Program Leader for 8100/8200 Range Improvements
Assists with 4322 and 4341 programs

Definitions:

Interpret

To explain or clarify the meaning or significance of: Scientists interpret data.

Interpretation

The act or process of interpreting; our explanation of the meaning of something unclear.

Interpreter

A person who explains or expounds on a certain subject.

LIST OF REFERENCES/READINGS

1. The Prairie
   J. E. Weaver and T.J. Fitzpatrick - University of Nebraska

2. Natural Resources and Public Relations
   Douglas L. Gilbert

3. Soil Conditions and Plant Growth
   E.W. Russell

4. Field Guide to Soils and the Environment
   Gerald W. Olson

5. National Soils Handbook
   Soil Survey Manual
   Soil Survey Staff USDA - S.C.S.

6. Soil Surveys & Land Use Planning
   Bartelli, L.J., A.A. Klingebill, J.V. Baird & M.R. Heddleson

7. Planning the Uses and Management of Land. Monograph 21
   American Society of Agronomy, Madison, WI.

8. The Tragedy of the Common's Revisited B.L. Crowe
   Science 166: 1103-1107

9. BLM Manual, 7000 - Soil, Water, and Air Management - 3/8/84

10. BLM Manual, 7100 - Soil Resource Management - 8/15/84

INTERPRETATIONS FROM SCS-5/SOIL SURVEY DATA

PROBLEM 1

Q: What is the Hydrologic Group of soil map unit 15 (McCone Co.)?

PROBLEM 2

Q: What is a seeding mixture for the same soil map unit (15)?

PROBLEM 3

Q: Will soil map unit 28 pose any problems for the construction of a pipeline? In map unit 24?

PROBLEM 4

Q: Which soil map units have potential for riparian concerns?

PROBLEM 5

INTERPRETATIONS FROM "SCRATCH"

Given:

A mechanical treatment (contour furrowing) has been done in one area for about 15 years. The few reports have indicated increases in production of 3 to 5 times as previously produced.

The prevailing thought is to start contour furrowing landscapes throughout the state to increase productivity.

As a group (planning team of Range, Soils, Wildlife, Hydrologists) you have been asked to approve and assess impacts of this mechanical treatment.

What is your reaction/evaluation to this proposal and how would you set up a soil interpretation for this?

SD0003 SOIL INTERPRETATIONS RECORD

MLRA(S): 53B
REV. LDZ. 4-79
TYPIC HAPLUBOROLLS, FINE-SILTY, MIXED

BRYANT SERIES

THE BRYANT SERIES CONSISTS OF DEEP, WELL-DRAINED, NEARLY LEVEL TO SLOPING SOILS FORMED IN CALCAREOUS SILTY DRIFT. THESE SOILS HAVE DARK GRAYISH-BROWN LOAM SURFACE LAYERS 8 INCHES THICK; GRAYISH-BROWN CLAY LOAM UPPER SUBSOILS; LIGHT BROWNISH-GRAY, LOAM LOWER SUBSOILS WITH COMMON SEGREGATIONS OF LIME; AND LIGHT BROWNISH-GRAY AND YELLOWISH-BROWN, LOAM UNDERLYING MATERIAL. SLOPES RAGNE FROM 0 TO 15 PERCENT. MOST AREAS ARE CULTIVATED.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-8	L, SIL	ML, CL, CL-ML	A-6, A-4	0	100	100	85-100	70-100	25-40	3-15
8-15	CL, SIL, SICL	CL, ML, CL-ML	A-6, A-4	0	100	100	85-100	70-100	25-40	3-15
15-60	CL, L, SIL	CL, ML, CL-ML	A-6, A-4	0	100	100	85-100	70-100	25-40	3-15

DEPTH (IN.)	CLAY (PCT <2MM)	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	T	WIND EROD. GROUP	ORGANIC MATTER (PCT)	CORROSIVITY STEEL	CONCRETE
0-8	18-26	1.10-1.25	0.6-2.0	0.18-0.20	6.1-7.3	-	LOW	.32	5	6	2-4	HIGH	LOW
8-15	22-35	1.20-1.35	0.6-2.0	0.19-0.22	6.6-7.8	-	LOW	.43					
15-60	22-35	1.20-1.35	0.6-2.0	0.17-0.20	7.4-8.4	-	LOW	.43					

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			>6.0			-		>60		-		B	MODERATE

SANITARY FACILITIES

SEPTIC TANK ABSORPTION FIELDS	0-8%: SLIGHT 8-15%: MODERATE-SLOPE
SEWAGE LAGOON AREAS	0-2%: MODERATE-SEEPAGE 2-7%: MODERATE-SLOPE, SEEPAGE 7+%: SEVERE-SLOPE
SANITARY LANDFILL (TRENCH)	0-8%: SLIGHT 8-15%: MODERATE-SLOPE
SANITARY LANDFILL (AREA)	0-8%: SLIGHT 8-15%: MODERATE-SLOPE
DAILY COVER FOR LANDFILL	0-8%: GOOD 8-15%: FAIR-SLOPE

BUILDING SITE DEVELOPMENT

SHALLOW EXCAVATIONS	0-8%: SLIGHT 8-15%: MODERATE-SLOPE
DWELLINGS WITHOUT BASEMENTS	0-8%: SLIGHT 8-15%: MODERATE-SLOPE
DWELLINGS WITH BASEMENTS	0-8%: SLIGHT 8-15%: MODERATE-SLOPE
SMALL COMMERCIAL BUILDINGS	0-4%: SLIGHT 4-8%: MODERATE-SLOPE 8+%: SEVERE-SLOPE
LOCAL ROADS AND STREETS	0-8%: MODERATE-LOW STRENGTH, FROST ACTION 8-15%: MODERATE-LOW STRENGTH, SLOPE, FROST ACTION
LAWNS, LANDSCAPING AND GOLF FAIRWAYS	0-8%: SLIGHT 8-15%: MODERATE-SLOPE

CONSTRUCTION MATERIAL

ROADFILL	FAIR-LOW STRENGTH
SAND	IMPROBABLE-EXCESS FINES
GRAVEL	IMPROBABLE-EXCESS FINES
TOPSOIL	0-8%: GOOD 8-15%: FAIR-SLOPE

WATER MANAGEMENT

POND RESERVOIR AREA	0-3%: MODERATE-SEEPAGE 3-8%: MODERATE-SEEPAGE, SLOPE 8+%: SEVERE-SLOPE
EMBANKMENTS DIKES AND LEVEES	SEVERE-PIPING
EXCAVATED PONDS AQUIFER FED	SEVERE-NO WATER
DRAINAGE	DEEP TO WATER
IRRIGATION	0-3%: FAVORABLE 3+%: SLOPE
TERRACES AND DIVERSIONS	0-8%: ERODES EASILY 8+%: SLOPE, ERODES EASILY
GRASSED WATERWAYS	0-8%: ERODES EASILY 8+%: SLOPE, ERODES EASILY

REGIONAL INTERPRETATIONS

PASTURE	GROUP F

BRYANT SERIES

SD0003

RECREATIONAL DEVELOPMENT

CAMP AREAS	0-8%: SLIGHT 8-15%: MODERATE-SLOPE	PLAYGROUNDS	0-2%: SLIGHT 2-6%: MODERATE-SLOPE 6+%: SEVERE-SLOPE
PICNIC AREAS	0-8%: SLIGHT 8-15%: MODERATE-SLOPE	PATHS AND TRAILS	SLIGHT

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY		CORN (BU)		OATS (BU)		WHEAT, SPRING (BU)		FLAX (BU)		ALFALFA HAY (TONS)		COOL SEASON GRASS (AUM)			
	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
0-2%	2C		35		53		28		16		2.0		3.3			
2-6%	2E		32		52		27		15		1.9		3.2			
6-9%	3E		30		44		22		-		1.6		2.7			
9-15%	4E		-		36		17		-		1.4		2.3			

WOODLAND SUITABILITY

CLASS-DETERMINING PHASE	ORD SYM	EROSION HAZARD	EQUIP. LIMIT	SEEDLING MORT'Y.	WINDTH. HAZARD	PLANT COMPET.	COMMON TREES	SITE INDX	TREES TO PLANT
							NONE		

(MANAGEMENT PROBLEMS: EROSION HAZARD through PLANT COMPET.; POTENTIAL PRODUCTIVITY: COMMON TREES, SITE INDX)

WINDBREAKS (A)

CLASS-DETERMIN'G PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
ALL	BLACK HILLS SPRUCE	20	PONDEROSA PINE	22	GREEN ASH	22	BUR OAK	18
	RUSSIAN-OLIVE	15	SIBERIAN CRABAPPLE	18	EASTERN REDCEDAR	14	COMMON CHOKECHERRY	10
	SIBERIAN PEASHRUB	9	AMERICAN PLUM	9	TATARIAN HONEYSUCKLE	10	LILAC	9

WILDLIFE HABITAT SUITABILITY

CLASS-DETERMINING PHASE	POTENTIAL FOR HABITAT ELEMENTS								POTENTIAL AS HABITAT FOR:			
	GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	OPENLD WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
0-2%	GOOD	GOOD	GOOD	GOOD	V. POOR	-	V. POOR	V. POOR	GOOD	V. POOR	V. POOR	GOOD
2-6%	GOOD	GOOD	GOOD	GOOD	V. POOR	-	V. POOR	V. POOR	GOOD	V. POOR	V. POOR	GOOD
6-9%	FAIR	GOOD	GOOD	FAIR	V. POOR	-	V. POOR	V. POOR	FAIR	V. POOR	V. POOR	GOOD
9-15%	POOR	GOOD	GOOD	POOR	V. POOR	-	V. POOR	V. POOR	POOR	V. POOR	V. POOR	GOOD

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION) (B)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE: ALL				
GREEN NEEDLEGRASS	STVI4	50				
WESTERN WHEATGRASS	AGSM	20				
NEEDLEANDTHREAD	STCO4	15				
BLUE GRAMA	BOGR2	5				
SEDGE	CAREX	5				
OTHER PERENNIAL FORBS	PPFF	5				
POTENTIAL PRODUCTION (LBS./AC. DRY WT):						
FAVORABLE YEARS		3400				
NORMAL YEARS		2800				
UNFAVORABLE YEARS		2000				

FOOTNOTES

A WINDBREAK GROUP 3
B SILTY RANGE SITE

MT0050

SOIL SURVEY INTERPRETATIONS

MLRA(S): 44, 46, 52, 58
REV. RER, 7-87
USTIC TORRIORTHENTS, LOAMY, MIXED (CALCAREOUS), FRIGID, SHALLOW

CABBART SERIES

THE CABBART SERIES CONSISTS OF SHALLOW, WELL-DRAINED SOILS FORMED IN WEATHERED SOFT SHALE, SILTSTONE OR SANDSTONE. TYPICALLY, THESE SOILS HAVE A LOAM SURFACE LAYER AND LOAM UNDERLYING MATERIAL OVER WEATHERED BEDROCK AT DEPTHS OF 10 TO 20 INCHES. THEY OCCUPY UPLANDS IN A 10 TO 14 INCH PRECIPITATION ZONE. THE NATIVE VEGETATION IS MAINLY WESTERN WHEATGRASS, NEEDLEANDTHREAD, BLUEBUNCH WHEATGRASS, FORBS AND SHRUBS. THE GROWING SEASON IS 105 TO 135 DAYS. SLOPES ARE 2 TO 60 PERCENT.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-3	L	CL-ML, CL	A-4	0	100	100	85-95	60-75	20-30	5-10
0-3	SIL	CL-ML, CL	A-4	0	100	100	90-100	75-90	20-30	5-10
3-18	L, CL, SICL	CL	A-6	0	100	100	85-100	65-95	30-40	10-20
18-60	WB									

DEPTH (IN.)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	CORROSIVITY STEEL	CORROSIVITY CONCRETE	EROSION FACTORS K	T	WIND EROD. GROUP
0-3	0.6-2.0	0.14-0.20	7.4-8.4	2-4	LOW	HIGH	MODERATE	.37	2	5
0-3	0.6-2.0	0.18-0.22	7.4-9.0	2-4	LOW	HIGH	MODERATE	.37	2	6
3-18	0.02-2.0	0.12-0.18	7.9-9.0	2-8	MODERATE	HIGH	MODERATE	.37		
18-60										

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			>6.0			-		10-20	RIPPABLE	-		C	MODERATE

SANITARY FACILITIES

SEPTIC TANK ABSORPTION FIELDS	2-15%: SEVERE-DEPTH TO ROCK ~~PERCS SLOWLY~~ 15+%: SEVERE-SLOPE, DEPTH TO ROCK ~~PERCS SLOWLY~~
SEWAGE LAGOON AREAS	2-7%: SEVERE-DEPTH TO ROCK 7+%: SEVERE-DEPTH TO ROCK, SLOPE
SANITARY LANDFILL (TRENCH)	2-25%: SEVERE-DEPTH TO ROCK 25+%: SEVERE-SLOPE, DEPTH TO ROCK
SANITARY LANDFILL (AREA)	2-8%: SLIGHT 8-15%: MODERATE-SLOPE 15+%: SEVERE-SLOPE
DAILY COVER FOR LANDFILL	2-15%: POOR-THIN LAYER, AREA RECLAIM 15+%: POOR-SLOPE, THIN LAYER, AREA RECLAIM

COMMUNITY DEVELOPMENT

SHALLOW EXCAVATIONS	2-8%: MODERATE-DEPTH TO ROCK, TOO CLAYEY 8-15%: MODERATE-SLOPE, DEPTH TO ROCK, TOO CLAYEY 15+%: SEVERE-SLOPE
DWELLINGS WITHOUT BASEMENTS	2-8%: MODERATE-DEPTH TO ROCK 8-15%: MODERATE-SLOPE, DEPTH TO ROCK 15+%: SEVERE-SLOPE
DWELLINGS WITH BASEMENTS	2-8%: MODERATE-DEPTH TO ROCK ~~SHRINK-SWELL~~ 8-15%: MODERATE-SLOPE, DEPTH TO ROCK, ~~SHRINK-SWELL~~ 15+%: SEVERE-SLOPE
SMALL COMMERCIAL BUILDINGS	2-8%: MODERATE-SLOPE, DEPTH TO ROCK, SHRINK-SWELL 8+%: SEVERE-SLOPE
LOCAL ROADS AND STREETS	2-15%: SEVERE-LOW STRENGTH 15+%: SEVERE-SLOPE, LOW STRENGTH
LAWNS, LANDSCAPING AND GOLF FAIRWAYS	

SOURCE MATERIAL

ROADFILL	2-25%: POOR-LOW STRENGTH, THIN LAYER, AREA RECLAIM 25+%: POOR-SLOPE, THIN LAYER, LOW STRENGTH
SAND	UNSUITED
GRAVEL	UNSUITED
TOPSOIL	2-15%: POOR-EXCESS SODIUM 15+%: POOR-SLOPE, EXCESS SODIUM

WATER MANAGEMENT

POND RESERVOIR AREA 2	SLOPE, DEPTH TO ROCK
EMBANKMENTS DIKES AND LEVEES	PIPING, THIN LAYER
EXCAVATED PONDS AQUIFER FED	NO WATER
DRAINAGE	
IRRIGATION	
TERRACES AND DIVERSIONS	2-8%: DEPTH TO ROCK, PERCS SLOWLY 8+%: SLOPE, DEPTH TO ROCK, PERCS SLOWLY
GRASSED WATERWAYS	SLOPE, EXCESS SODIUM, ERODES EASILY

REGIONAL INTERPRETATIONS

RECREATION

CAMP AREAS	2-8%: SLIGHT 8-15%: MODERATE-SLOPE 15+%: SEVERE-SLOPE	PLAYGROUNDS	2-6%: SEVERE-DEPTH TO ROCK 6+%: SEVERE-SLOPE,DEPTH TO ROCK
PICNIC AREAS	2-8%: SLIGHT 8-15%: MODERATE-SLOPE 15+%: SEVERE-SLOPE	PATHS AND TRAILS	2-15%: SLIGHT 15-25%: MODERATE-SLOPE 25+%: SEVERE-SLOPE

CAPABILITY AND PREDICTED YIELDS -- CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY															
	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
4-15%	6E	-														
15+%	7E	-														

WOODLAND SUITABILITY (A)

CLASS-DETERMINING PHASE	ORD SYM	MANAGEMENT PROBLEMS: EROSION HAZARD	EQUIP. LIMIT	SEEDLING MORT'Y.	WINDTH. HAZARD	PLANT COMPET.	POTENTIAL PRODUCTIVITY: IMPORTANT TREES	SITE INDX	TREES TO PLANT
							NONE		

WINDBREAKS

CLASS-DETERMINING PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
	NONE							

WILDLIFE HABITAT SUITABILITY

CLASS-DETERMINING PHASE	POTENTIAL FOR HABITAT ELEMENTS: GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	POTENTIAL AS HABITAT FOR: OPENLD WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
4-15%	POOR	FAIR	POOR	-	-	POOR	V. POOR	V. POOR	POOR	-	V. POOR	POOR
15+%	V. POOR	V. POOR	POOR	-	-	POOR	V. POOR	V. POOR	V. POOR	-	V. POOR	POOR

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE: 10-12 MAP	12-14 MAP				
BLUEBUNCH WHEATGRASS	AGSP	10	-				
GREEN NEEDLEGRASS	STVI4	15	-				
NEEDLEANDTHREAD	STCO4	10	10				
WESTERN WHEATGRASS	AGSM	25	5				
SANDBERG BLUEGRASS	POSE	5	-				
PRAIRIE JUNEGRASS	KOCR	5	-				
PLAINS REEDGRASS	CAMO	10	-				
SAND DROPSEED	SPCR	5	-				
BLUE GRAMA	BOGR2	5	10				
OTHER ANNUAL FORBS	AAFF	5	-				
OTHER SHRUBS	SSSS	5	10				
LITTLE BLUESTEM	ANSC2		40				
SIDEOATS GRAMA	BOCU		15				
OTHER PERENNIAL FORBS	PPFF		10				
POTENTIAL PRODUCTION (LBS./AC. DRY WT): FAVORABLE YEARS		800	1560				
NORMAL YEARS			1300				
UNFAVORABLE YEARS		400	910				

FOOTNOTES

1 STRATA WITHIN BEDROCK MAY HAVE A HIGH SHRINK-SWELL POTENTIAL.

A LOW DENSITY STANDS OF PONDEROSA PINE AND ROCKY MOUNTAIN JUNIPER GROW ON SOME SOIL AREAS.

2 CHECK PERMEABILITY OF BEDROCK TO SEE IF SEEPAGE IS A SEVERE LIMITATION FOR POND RESERVOIR AREAS.

Montana BLM
March 1984

RANGELAND MECHANICAL TREATMENT GUIDE

When it has been determined that grazing management systems cannot reach desired goals in a realistic time, mechanical treatments with good grazing management practices can be considered.

The following information will be useful in selecting appropriate land treatments.

Pros and Cons of Rangeland Mechanical Treatment and Fertilization

The following conclusions on rangeland mechanical treatment and fertilization are drawn from: 1. Research, 2. Field observations and 3. Ranchers' experience.

These treatments are designed to improve livestock grazing, watershed condition, wildlife habitat and recreation. These mechanical treatments result in long term benefits of 20 years, or more.

Mechanical Treatments

I. Scalping and Furrowing

A. Advantages

1. Increases vegetative production, diversity and vigor.
2. Reduces runoff - captures moisture on site.
3. Increases soil moisture available for plant growth.
4. Provides forage during drier years.
5. Provides opportunities for seeding.
6. Improves vegetative ground cover.
7. Improves water quality.

B. Disadvantages

1. Livestock and wildlife dislike traversing furrows.
2. Extra forage may not be used if animals have another grazing choice.
3. May cause overuse of untreated areas in same pasture.
4. Reduces runoff into reservoirs.
5. Livestock can be trapped when lying down.
6. Equipment is not available to many ranchers.
7. Equipment and maintenance costs are high.
8. Labor intensive; extra care must be taken to lay out furrows on contour.
9. Restricts vehicle use.

II. Chiseling

A. Advantages

1. Increases vegetative production, diversity and vigor.
2. Equipment is available to many ranchers.
3. Movement of vehicles, livestock and wildlife are only slightly altered.
4. Increases soil moisture for plant growth.
5. Increases vegetative ground cover.
6. Easy to lay out and complete - exact contour is not necessary.
7. Chiseling equipment is flexible, shovel size, and nature of shank (straight or twisted) can be selected for soil and vegetation conditions.

B. Disadvantages

1. May be less productive than scalping or furrowing on most sites.
2. May require two passes to reach desired soil and vegetative disturbance, thus costs may be increased.

Range Fertilization

A. Advantages

1. Increases vegetative production
2. Increases nutrition and palatability of forage
3. Draws animals into areas not ordinarily used.
4. Increases vegetative ground cover reducing runoff and erosion

B. Disadvantages

1. Management needs are increased to prevent the following problems:

a. Vegetation tends to go to monoculture (favoring most vigorous species).

b. Undesirable vegetative species may increase (due to overuse of palatable species).

c. Vegetation and soils on small fertilized areas may be damaged due to concentration of animals.

2. Ecological condition may decrease.

Montana BLM
March 1984

SUITABILITY GUIDE FOR RANGELAND MECHANICAL TREATMENTS

The following guide has been developed by BLM Soil Scientists, and other specislists, for use on Montana and Dakota public lands.

Mechnical treatments may be considered as an alternative method of increasing vegetative production and improving watershed condition. Treatment feasibility should be considered where grazing management systems cannot reach desired goals in a realistic time.

Factors influencing feasibility of treatments are: (1) soil properties, (2) existing plant community, (3) objectives of treatment, (4) anticipated response from treatment, (5) economics, (6) availability of equipment, (7) conditions that influence operation of equipment.

The objectives of mechanical treatment should be carefully analyzed. It may be desirable to: (1) change existing vegetation (i.e., reduce clubmoss-blue grama dominance) and/or (2) correct a soils problem (i.e., breakup of claypan or compacted layer). Vegetation can be changed to improve range condition or to maximize production. Treatment should be selected to best reach the desired objective.

To use the table, first consider each factor in the left column independent of others, then consider interrelated factors to reach a final rating. These are evaluated in the following table.

Relevant conditions not evaluated in the table must also be considered. For example, kinds of bedrock (i.e., consolidated, fractured, etc.) will influence suitability for mechanical treatments. Aspect will influence the amount of moisture available for plant use.

[illegible]
[illegible]

SUITABILITY GUIDE FOR RANGELAND MECHANICAL TREATMENTS

The following guide has been developed by the Soil Scientists, and range specialists, for use in Montana and Dakota public lands.

Mechanical treatment may be considered as an alternative method of increasing vegetative production and improving watershed condition. Treatment feasibility should be considered where grazing management systems cannot reach desired goals in a reasonable time.

Factors influencing feasibility of treatment are: (1) soil properties, (2) existing plant community, (3) objectives of treatment, (4) anticipated response from treatment, (5) economics, (6) availability of equipment, (7) conditions that influence operation of equipment.

The objectives of mechanical treatment should be carefully analyzed. It may be desirable to: (1) change existing vegetation (i.e., reduce sagebrush-blue grama dominance) and/or (2) correct a soil problem (i.e., breakup of claypan or compacted layer). Vegetation may be changed to improve range condition or to maximize production. Treatment should be selected to best reach the desired objective.

To use the table, first consider each factor in the left column independent of others, then consider interrelated factors to reach a final rating. These are evaluated in the following table.

Economic conditions are considered in the table only to the extent, for example, kinds of [illegible] (i.e., [illegible], [illegible], etc.) will influence suitability for mechanical treatment. Terrain will influence the amount of equipment available for given use.

Treatment effect upon water infiltration and runoff is an important consideration. Many treatments will increase infiltration and reduce runoff; but less runoff may not be desirable in cases where downstream use of water has a higher priority.

Wildlife Considerations

Mechanical treatment of sagebrush land should not be done on sage grouse or sharptail strutting grounds, or on nesting or other special use areas. No vegetal control should be attempted along streams, meadows or secondary drainages (dry and intermittent) unless done as part of a planned meadow rehabilitation effort. Normally, a buffer strip of living sage should be retained on each edge of meadows and drainages. Onsite inspections by wildlife personnel should be made to determine these.

Projects to control sagebrush should be designed in irregular patterns. Design should consider natural terrain, vegetative types, brush density, sage grouse special use areas and other habitat needs. No large blocks of sagebrush should be treated in occupied sage grouse range, or on antelope or deer winter range.

SUITABILITY GUIDE FOR RANGELAND MECHANICAL TREATMENT 1/

Property Affecting Use	Chiseling or Scalping: Suited	Chiseling or Scalping: Unsuited	Contour Furrowing: Suited	Contour Furrowing: Unsuited	Plowing and Seeding: Suited	Plowing and Seeding: Unsuited
Slope	≤ 15%	> 15%	≤ 15%	> 15%	≤ 8%	> 8%
Depth to Bedrock (Paralithic) 2/	≥ 20"	< 20"	≥ 20"	< 20"	≥ 20"	< 20"
Calcium Carbonate 3/	≤ es	ev	≤ e	≥ es	≤ e	≥ es
Texture of Surface Layer 3/	All textures except cos, s, fs, lfs, ls	cos, s, fs, lfs, ls	All textures except cos, s fs, lfs, ls	cos, s, fs, lfs, ls	All textures except cos, s fs, lfs, ls	cos, s, fs, lfs, ls
Coarse Fragments In Surface Layer; (vol.) Gravel + Cobbles Stones + Boulders	≤ 35% < 3%	> 35% > 3%	≤ 35% < 3%	> 35% > 3%	≤ 35% < 3%	> 35% > 3%
Salts (mmhos/cm) 3/ SAR 3/	< 12 < 12	> 12 ≥ 12	< 12 < 12	> 12 ≥ 12	≤ 4 ≤ 4	> 4 > 4
Structure of Surface Layer	All except those in unsuited.	Single grained w/coarse texture or 40% clay w/ massive or vesicular crust.	All except those in unsuited.	Single grained w/coarse texture or 40% clay w/ massive or vesicular crust.	All except those in unsuited.	Single grained w/coarse texture or 40% clay w/ massive or vesicular crust.
Flooding Hazard	None to occasional	Frequent	None to occasional	Frequent	None to occasional	Frequent
Drainage Class	All except those in unsuited.	Excessively drained; poor or very poorly drained.	All except those in unsuited.	Excessively drained; poor or very poorly drained.	All except those in unsuited.	Excessively drained; poor or very poorly drained.
Tree Canopy Cover	< 10%	> 10%	< 10%	> 10%	0	> 0

1/ An on-site examination is necessary to determine if the landscape is suited for specific kinds of mechanical treatments, e.g., are shallow soils, steep slopes, or dissection in the landscape as limiting factors.

2/ Unconsolidated when moist.

3/ Applies to surface layer (upper 6 to 8 inches).

Sedimentary Plains, Mountains, and Foothills
15 to 19 Inch PZ

SUITABILITY GUIDE FOR RANGELAND MECHANICAL TREATMENT 1/

Property Affecting Use	Chiseling or Scalping: Suited	Chiseling or Scalping: Unsuited	Contour Furrowing: Suited	Contour Furrowing: Unsuited	Plowing and Seeding: Suited	Plowing and Seeding: Unsuited
Slope	$\leq$ 15%	> 15%	$\leq$ 15%	> 15%	$\leq$ 15%	> 15%
Depth to Bedrock (Paralithic) 2/	$\geq$ 20"	< 20"	$\geq$ 20"	< 20"	$\geq$ 20"	< 20"
Calcium Carbonate 3/	$\leq$ es	ev	$\leq$ e	$\geq$ es	$\leq$ e	$\geq$ es
Texture of Surface Layer 3/	All textures except cos, s, fs, lfs, ls	cos, s, fs, lfs, ls	All textures except cos, s fs, lfs, ls	cos, s, fs, lfs, ls	All textures except cos, s fs, lfs, ls	cos, s, fs, lfs, ls
Coarse Fragments In Surface Layer; (vol.)						
Gravel + Cobbles	$\leq$ 35%	> 35%	$\leq$ 35%	> 35%	$\leq$ 35%	> 35%
Stones + Boulders	$\leq$ 3%	> 3%	$\leq$ 3%	> 3%	$\leq$ 3%	> 3%
Salts (mmhos/cm) 3/	< 12	> 12	< 12	> 12	$\leq$ 4	> 4
SAR 3/	< 12	$\geq$ 12	< 12	$\geq$ 12	$\leq$ 4	> 4
Structure of Surface Layer	All except those in unsuited.	Single grained w/coarse texture or 40% clay w/ massive or vesicular crust.	All except those in unsuited.	Single grained w/coarse texture or 40% clay w/ massive or vesicular crust.	All except those in unsuited.	Single grained w/coarse texture or 40% clay w/ massive or vesicular crust.
Flooding Hazard	None to occasional	Frequent	None to occasional	Frequent	None to occasional	Frequent
Drainage Class	All except those in unsuited.	Excessively drained; poor or very poorly drained.	All except those in unsuited.	Excessively drained; poor or very poorly drained.	All except those in unsuited.	Excessively drained; poor or very poorly drained.
Tree Canopy Cover	< 10%	> 10%	< 10%	> 10%	< 10%	> 10%

1/ An on-site examination is necessary to determine if the landscape is suited for specific kinds of mechanical treatments, e.g., are shallow soils, steep slopes, or dissection in the landscape as limiting factors.

2/ Unconsolidated when moist.

3/ Applies to surface layer (upper 6 to 8 inches).

Montana BLM
March 1984

Glaciated Plains
10 to 14 and 15 to 19 Inch PZ

SUITABILITY GUIDE FOR RANGELAND MECHANICAL TREATMENT 1/

Property Affecting Use	Chiseling or Scalping: Suited	Chiseling or Scalping: Unsuited	Contour Furrowing: Suited	Contour Furrowing: Unsuited	Plowing and Seeding: Suited	Plowing and Seeding: Unsuited
Slope	≤ 15%	> 15%	≤ 15%	> 15%	≤ 15%	> 15%
Depth to Bedrock (Paralithic) 2/	≥ 20"	< 20"	≥ 20"	< 20"	≥ 20"	< 20"
Texture of Surface Layer 3/	All textures except cos, s, fs, lfs, ls	cos, s, fs, lfs, ls	All textures except cos, s fs, lfs, ls	cos, s, fs, lfs, ls	All textures except cos, s fs, lfs, ls	cos, s, fs, lfs, ls
Coarse Fragments In Surface Layer; (vol.)						
Gravel + Cobbles	≤ 35%	> 35%	≤ 35%	> 35%	≤ 35%	> 35%
Stones + Boulders	≤ 3%	> 3%	≤ 3%	> 3%	≤ 3%	> 3%
Salts (mmhos/cm) 3/	≤ 12	≥ 12	≤ 12	≥ 12	≤ 4	> 4
SAR 3/	< 12	≥ 12	< 12	≥ 12	≤ 4	> 4
Structure of Surface Layer	All except those in unsuited.	Single grained w/coarse texture or 40% clay w/ massive or vesicular crust.	All except those in unsuited.	Single grained w/coarse texture or 40% clay w/ massive or vesicular crust.	All except those in unsuited.	Single grained w/coarse texture or 40% clay w/ massive or vesicular crust.
Flooding Hazard	None to occasional	Frequent	None to occasional	Frequent	None to occasional	Frequent
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Tree Canopy Cover	0	> 0	0	> 0	0	> 0

1/ An on-site examination is necessary to determine if the landscape is suited for specific kinds of mechanical treatments, e.g., are shallow soils, steep slopes, or dissection in the landscape as limiting factors.

2/ Unconsolidated when moist.

3/ Applies to surface layer (upper 6 to 8 inches).

SELECTION OF LAND TREATMENT BY RANGE SITE

In addition to the foregoing interpretation guide on the suitability of soils and related factors for rangeland mechanical treatment, it may be helpful to consider the selection of land treatment according to range sites.

The following table shows the type of treatment (mechanical, burning or chemical) suited to correct common soil or vegetation problems found on certain range sites. Where two or more vegetation or soil problems are present (dense sagebrush on claypan soils) select the treatment that will solve both problems; the claypan problem cannot be reduced just by burning sagebrush. Range sites not shown in the table are generally unsuited to mechanical treatments.

Note that vegetative changes can be accomplished with fire, chemicals or a surface layer treatment (i.e., chiseling) but to correct a subsoil problem may require a deeper treatment (i.e., furrowing or deep chiseling).

Additional factors must be considered to determine the final suitability of a site for mechanical treatment. These factors are in the foregoing section, on rating soil properties and related factors. The narrative discusses objectives of a treatment.

Finally, land treatments cannot be considered an alternative to good management practices, but will require a high level of management following the treatments.

GUIDE TO TREATMENT SELECTION BY DOMINANT RANGE SITE 1/

Vegetation or Soil Problem	CLAY PAN	CLAYEY	DENSE CLAY 2/	OVERFLOW	SANDY	SILTY	SHALLOW 3/
Blue grama and/or clubmoss	A4, A2, A1, A3 C1, C3, C2 D1, D2	A3, A2, A1 B1, B3, B2 D1, D2	N/A	A1, A2, A3, A4 D1, D2	A3, A2, A1 D1, D2	A3, A2, A1 B1, B2, B3 D1, D2	
Claypan	A4, A2, A1, A3 C1, C3, C2 D1, D2	N/A	N/A	N/A	N/A	N/A	
Compaction Suface Layer down to 8 inches	A3, A2, A1 B1, B3 D1	A3, A2, A1 B1, B2, B3 D1, D2	A2, A1 C1, C3	A2, A1, A3 D1	A3, A2, A1 D1, D2	A3, A2, A1 B1, B3, B2 D1, D2	
Subsoil below 8 inches	A4 C1, C3	A4 C1, C2, C3 D1, D2	N/A	A4 D1	N/A	A4	
Dense big sage-brush (30% cover)	E, G D2	E, G, D2	E, G	N/A	N/A	E, G D2	
Weedy or nearly barren areas	C2 D2, D1	D1, D2 B2, B1 C2 A2, A3, A1	A2, A1 C2	A2, A3 D1, D2	D1, D2	D1, D2 B2 C2	
Borrow areas 4/	D1, D2 F	D2, D2 F	D1, D2 F	D1, D2 F	D1, D2 F	D1, D2 F	

1/ Make choice of treatments based on range condition, planned grazing system, available equipment, desire of permittee and benefit/cost. The order of listed options may be changed based on local conditions.

These range sites are dominant in the treatment area.

2/ Good range management is usually the most economical choice of treatment due to the low production potential on this range site.

3/ Inclusions of shallow soils, if treated, will be given the same mechanical treatment as the dominant soil/range site.

4/ Saving and replacing the topsoil is the first concern on these areas.

NOTE: Fertilizer is a tool that can be used to encourage better livestock distribution in addition to other uses.

KEY TO TREATMENTS ON RANGELAND

A. Chiseling at 4-6 inch depth

- A1 Using straight shanks - 2 operations (last on contour)
- A2 Using twisted shanks - 2 operations (last on contour)
- A3 Using 6-inch shovels (sweeps) - 1 operation (on contour)
- A4 Deep chiseling at 6 to 10-inch depth - 2 operations - (last on contour)

B. Contour scalping at 2-4 inch depth

- B1 Interseed with alfalfa
- B2 Interseed with grass and alfalfa
- B3 No interseeding

C. Contour furrowing at 4 to 10-inch depth

- C1 Interseed with alfalfa
- C2 Interseed with grass and alfalfa
- C3 No interseeding

D. Seedbed preparation and seeding

- D1 Two operations with chisel, then third operation with drill attached.
- D2 Plow and seed

E. Burning

F. Fertilizing

G. Chemical

GIS

Course 7000.1
Instructors: Foster
Webster

GEOGRAPHIC INFORMATION SYSTEMS

Objectives

1. To understand the GIS technology, its status in BLM, and its possible applications in soil, water, and air management.

2. To use a GIS to create maps and solve simplified problems in planning and watershed analysis.

Topic Outline

I. GIS - What is it?

   A. Definition - a means of digitally representing spatial data for the purpose of data analysis.

   B. Data Capture

      1. Points, lines, and polygons

      2. Sub-systems available in BLM

   C. Data Analysis

      1. Map Overlay and Statistical System (MOSS)
      2. Map Analysis Processing System (MAPS)

   D. Data Output

      1. Cartographic Output System (COS)

      2. MOSS and MAPS capabilities

II. GIS - Where is it?

III. GIS - How is it used?

   A. Soil Landscape Analysis Project (SLAP)

   B. Other applications

IV. Hands-On

   A. A walk through of commands necessary to get started

   B. Basic exercise to build familiarity and confidence

   C. Watershed exercise

V. Question/Answer Review Session

hn W. Foster D-443 Denver Service Center (303)236-0100 FTS 776-0100

1965-1969 U.S. Air Force - Computer Systems Specialist
Adana, Turkey and Siagon, Vietnam
Burroughs, UNIVAC, and IBM programmming and system design

1970-1974 Connecticut State University - Degree in Biological Sciences minors in environmental chemistry, mathematics, and computer science

1975-1977 Montana State University - Masters of Range Science with a minor in soils science

1977-1979 Rio Grande Resource Area Range Conservationist, BLM Albuquerque District Established Rio Grande Water Quality and Monitoring study and completed MFP for Rangeland Resources along with normal range program demands.

1979-1983 Taos Resource Area lead Range Conservationist, BLM Alburquerque District Designed and implemented range inventory and monitoring studies, completed pilot Landsat project along with normal range program duties.

1983-1984 DSC, Branch of Remote Sensing, Natural Resource Specialist Established new Remote Sensing Training course, lead project manager for Kemmerer, Pinedale, Washakie, Wyoming and Soda Springs, Idaho Remote sensing Projects.

1984-present DSC, Branch of Applications Assistance, Natural Resource Specialist, Project leader for Soil Landscape Analysis Project Tonopah, Nevada, and Arizona Strip Projects. Lead coordinator in GIS applications for Renewable Resources, State Implementation Plans and Technical Support for peripheral equipment procurement.

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GEOGRAPHIC INFORMATION SYSTEM
APPLICATIONS IN WATERSHED ANALYSIS

APRIL 23, 1986
8:00 - 10:00 AM

I. INTRODUCTION TO GIS

A. WHAT IS A GEOGRAPHIC INFORMATION SYSTEM

1. SOFTWARE CURRENTLY USED BY THE BLM

2. HARDWARE REQUIREMENTS FOR GIS

B. WHAT DOES THE GIS DO?

1. SPATIAL DATA

2. ANALYSIS

- RECLASSIFY
- OVERLAY
- DISTANCE
- NEIGHBORHOOD

10:00 - 10:15AM BREAK

10:15 - 11:30AM

II. HANDS-ON INTRODUCTION

A. LOGON PROCEDURE

B. BASIC COMMANDS

MOSS COMMANDS		MAPS COMMANDS	
OPEN	ACTIVE	OPEN	LIST
LIST	WINDOW	DESCRIBE	WINDOW
SELECT	PLOT	PLOT	INTERSECT
ACTIVE	BYE	CATERGORIZE	EXPLAIN
HELP	OVERLAY	AREA	BYE

C. ANALYSIS EXERCISE

D. HAND-OUT AFTERNOON EXERCISE FOR DISCUSSION

11:30 - 12:30 LUNCH

12:30 - 4:30PM

III. WATERSHED ANALYSIS EXERCISE AND OPEN DISCUSSION

AN INTRODUCTION TO GEOGRAPHIC INFORMATION SYSTEMS

By Solomon Katz, and the Staff of the Division of Advanced Data Technology, U.S. Bureau of Land Management

Geographic Information Systems (GIS) have been around for at least 20 years. Only recently have the costs of computer hardware declined to the point that small companies, and even individuals, can afford to maintain a GIS. GIS technology can be used to manipulate spatial information and data, whether derived from a map or other source. A GIS includes an automated filing system for the spatial data, but is most valuable as an analytical tool.

As geologists, we are accustomed to using maps in our work. Manual geographic information storage can simply involve map files or storage cabinets, from which we retrieve data either by memory or by using some sort of index system. To combine, analyze, and and later display the results of our work forced us into time-consuming manual drafting and cartography, hand planimetry, grid-cell sampling, and visual interpretation of the data.

A GIS is a computer system designed to store, process, and analyze spatial data. In some respects, geographic information systems are similar to other automated information systems in that they involve the following:

- Data acquisition: the collection and gathering of data;
- Data compilation: for plotting data onto a coordinate correct base, i.e., map or orthophotoquad;
- Data capture: the transformation of data into machine readable form, and their storage and organization within the computer;
- Editing, updating, and reclassifying of the data files;
- Manipulation, analysis, synthesis, and retrieval of data for user defined areas;
- Generation of a variety of outputs and reports.

But the ways in which these functions are performed are for the most part very different from other information systems—a result of the most significant characteristic of the GIS. Data in a GIS is of spatial or geographic nature, and must be georeferenced, that is, it must be tied to locations on the surface of the earth.

Data for geographic information systems can be gathered from a variety of sources: maps, aerial photographs, field surveys, private and public databases, assessor's records, image processing and census tapes. Data in a GIS can be divided into two basic classes: geographic and descriptive. Geographic data is related to the spatial nature of the item, things that can best be shown on a map. It shows the geographic location, size, and shape of a unit of data,such as the shape of a rock outcrop or oil well locations. Descriptive data refer to the characteristics or attributes of the unit, such as well ownership, trace element concentrations, and formation names. One physical unit of data may have one or several attributes to describe it. The geographic location of a unit of data can be represented horizontally with an (x,y) coordinate or some other geo-referencing system. In addition, a third coordinate (z) can represent a third dimension such as elevation to provide a vertical reference such as depth to a producing horizon, or thickness of a coal bed.

The geographic data structure is a dominant aspect of a system and provides the basis for classifying a GIS. The data structure refers to the organization of the data stored in the computer. Structure influences the way data are collected, their resolution and validity, data volume, and the types of analyses, the types of products that can be produced. The two most common geographic data structures are vector (line oriented) and raster (grid oriented). All geographic data can be broken down into either points, lines, or polygons.

Points are used to identify locations of features that have no significant areal extent (mine shafts, oil wells, section corners, etc). The data structure is usually a list of (x,y) coordinates with whatever descriptive data (attributes) are associated with the points.

Lines are used for linear data like pipelines, fault lines, roads, and road networks, assuming that these variables have no significant areal extent. In vector systems, lines are described by strings of (x,y) coordinates with the beginning and ending points of the line segments called nodes. Descriptive labels, such as San Andreas Fault, are assigned to the line segments between nodes.

Polygons are used for data that has an areal extent i.e., oil basins, rock outcrops, tracts of land, census districts, and counties. These all show areas. In a vector system, they are described as a list of (x,y) coordinates, with the first and last coordinate pair being the same.

Geographic data can be classified by their persistence. Certain types of data, such as geologic features, natural vegetation, and soil classifications are fairly stable and, once entered accurately, can remain unchanged for long periods of time. Dynamic data includes such things as mine boundaries, urban land use, and weather samples. The frequency of updating and/or revision has to be considered before deciding to use a GIS. If your data changes often, you may spend more time updating the GIS then using it. Data editing can be conducted on the data entry system or the analysis system.

Analysis of data is the primary function of a computerized GIS. Typical analyses might include calculation of area, overlaying and compositing, or calculation of proximity. These types of analyses distinguish a GIS from a computer mapping system. With any analysis, the geographic data are manipulated in concert with descriptive data. With a grid structure, the attributes are stored within the matrix and the geographic location is inherent in the structure of the matrix. Due to this, most manipulations are performed more efficiently with the grid structure, since polygon structures explicitly store both attribute and location. Some systems convert from vector to raster for processing, then back again for display. Vector systems persist because their products are more pleasing to look at.

In terms of minimum data functions, no standard definition of a GIS exists. A GIS can be differentiated from a computer mapping system by its analytical capabilities. If the manipulative techniques of search, measurement, and comparison are not needed, a GIS is not needed. These manipulation techniques are more powerful when the results can be retrieved and displayed with a GIS for human evaluation. Most queries on a geographic data base will involve combinations of these three components and can range from very simple to very complex.

Searching is the capability to read the entire file of geographic data and retrieve any required data by location, attribute or specific attribute value. The following are examples of search queries:

Locate all outcrops – simple search on an attribute (rock).

Locate all dikes – simple search on a specific attribute value (igneous intrusives).

Locate outcrop with largest area – same as previous query except the location data are specified by area, a measurement technique.

Locate any outcrop within 1 mile of a specific fault line – this time the search criterion is based on the attribute and location from another data set (fault lines). The specification of a search radius (measurement of distance) is called proximity.

Locate all outcrops with high mining potential – search based on criteria from multiple data sets. For instance, mining potential might consider the nearness of faults and/or intrusives, the presence of specific accessory minerals, assay values, rock type, etc.

Though these do not include all the possible types of queries, they show how queries are built using the search, measurement, and comparison techniques. Measurement is one of the most frequently performed manipulations. Location measurement functions include counting of points, lines, nodes or arcs, and calculating of area, perimeter, distance, and direction.

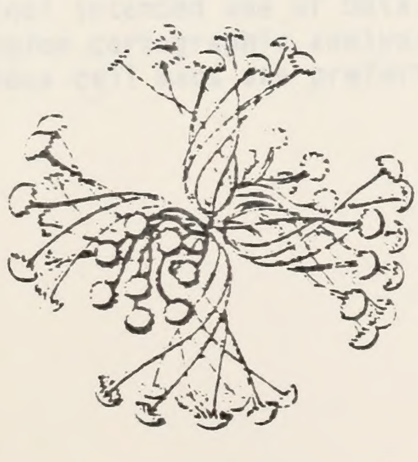
Comparison is probably the most powerful capability of a GIS. It is defined as the use of descriptive or location data to determine relationships based on criteria from one or both types of data. The two basic comparative techniques are overlaying/compositing and inferential statistics, i.e., regression and correlation. These two techniques, combined with techniques from the search and measurement capabilities, lead to the creation of new data sets and sophisticated model building, such as the above example where "high mining potential" was determined.

Although the definitions of overlaying and compositing are slightly different, their concept is essentially the same. Conceptually, compositing is the ability to overlay different layers of data on top of one another. Compositing is analogous to peering down through numerous map overlays to examine areas of coincidence. The computer allows any combination of data sets to be composited without the inherent visual restrictions of the human eye.

Most systems also have a statistical analysis subsystem that performs a variety of statistical operations. Of these, spatial correlation or the degree to which one data set corresponds to another is used most often. For example, the correlation between changes in land use and changes in water quality in a given area might be determined.

Some of the more common manipulations involve combinations of search, measurement and comparison. Some examples are listed below:

- Intervisibility: From a given point, determine the extent of the visual landscape. Used in viewshed analysis.
- Interpolation: From a sample of points, determine points or lines of equal value. Used for contouring maps.
- Corridor delineation: From a number of criteria, find a corridor for a power line, road, or other linear feature.
- Slope: Determine degree of slope associated with different land units.
- Aspect: Determine directional orientation of the slope for a land unit.
- Agregation/disagregation: Agregation involves the reclassification of data into broader categories. For example, soil types might be combined into soil association categories. Soil types may also be grouped according to their drainage characteristics. Disagregation involves the reclassification of categories into finer detail. For example, rock type classified as "igneous" might be redefined as granite or rhyolite. Disaggregation is possible only if the more detailed classes were entered when the data were created.



- Projection and scale change: During the entry stage, map projection and scale may have to be transformed to match that of the data base. During the retrieval stage, the map may be drawn at a specified projection or scale.
- Centroid allocation: Calculation of a single point, usually at the center of the polygon, to represent the polygon in various manipulations. Problems occur when the polygon is concave such as arc-shaped outcrop, because the computer may position the centroid outside the polygon.
- Line smoothing and simplification: Points are added to lines in smoothing to give the appearance of smooth, manually drawn lines for output. Points are deleted from lines in simplification. This is important for eliminating clutter and merging lines when the scale of the plot is much smaller than the scale of the digitized source. Occasionally smoothing will move lines so they no longer honor some original data points.
- Windowing: The ability to extract data from boundary coordinates, which is often used on display terminals to modify or zoom in on a particular portion of a data base.

Something rarely mentioned when introducing GIS is cost. Cost can range from free (public domain) to in excess of $100,000. Public domain GIS software can range from the very primitive to the very sophisticated. Sophisticated systems include Garnet, supported by the USGS National Coal Resources Program, and MOSS, supported by the BLM and several other Federal agencies. As with most public domain software, public domain GIS software is not on the leading edge of technology, often trailing from 1 to 3 years behind the newest commercial GIS packages.

In conclusion, GIS is not for everyone or even every company that uses maps. There is a start up cost involved when first transfering data from paper to computer readable material (tape, disks, etc). There is the recurring discovery that another piece of hardware will make the GIS better, faster, more accurate. There will be the time spent constantly updating digital map files. There will be the times the computer is down and you must have the information immediately. Yet in spite of all this, many geologists have found it worth the trouble to put their spatial data into a GIS. Maybe it will be worth it to you. □

1. INTRODUCTION

The Geographic Information System (GIS) is a set of software for encoding, transformating, analyzing, and displaying map and other geo-based information. Originally developed by the Western Energy and Land Use Team (WELUT) of the U.S. Fish and Wildlife Service (USFWS), the GIS has since been adopted by several other federal and state agencies. This system is composed of three components: Analytical Mapping System (AMS) for digital data-entry; Map Overlay and Statistical System (MOSS including MAPS) for data processing, analysis, and display; and Cartographic Output System (COS) for enhanced cartographic plotting.

MOSS has been designed to allow users to retrieve, analyze, and display maps and other spatial data stored in the system. Map data may be stored in two formats: vector; and cell or raster (Fig. 1). Vector data consist of series of (x,y) coordinates forming points, lines or polygons. Each feature in a vector map may be assigned an identifying attribute based on its characteristics. Cell data consist of a regular grid pattern in which each cell in the grid is assigned an identifying value based on its characteristics. Cell data may be created from vector data, a process called rasterizing. Because information from vector maps is generalized into cells by this conversion, vector maps may not be created from cell maps. Accuracy, resolution, storage, and processing of cell maps is directly related to grid-cell size. Some data, e.g., Landsat satellite imagery, originate in raster format.

In MOSS, cell maps are most specifically handled by software referred to as the MAPS sub-system. Map format, command syntax, and data retrieval characteristics are different, therefore, vector processing capabilities will be referred to as MOSS whereas raster capabilities will be referred to as MAPS. Although MOSS and MAPS may be accessed together, they may also act as stand-alone systems. Limited raster processing capabilities exist within MOSS (Appendix C). Note that vector maps and data used in MOSS may be used in MAPS, but cell data used or created in MAPS may not be used in MOSS. Choice of data format will largely depend on the final intended use of data. In general, vector maps are preferred for high precision cartographic analysis and aesthetically pleasing cartographic output whereas cell maps are preferred for complex cartographic modeling procedures.

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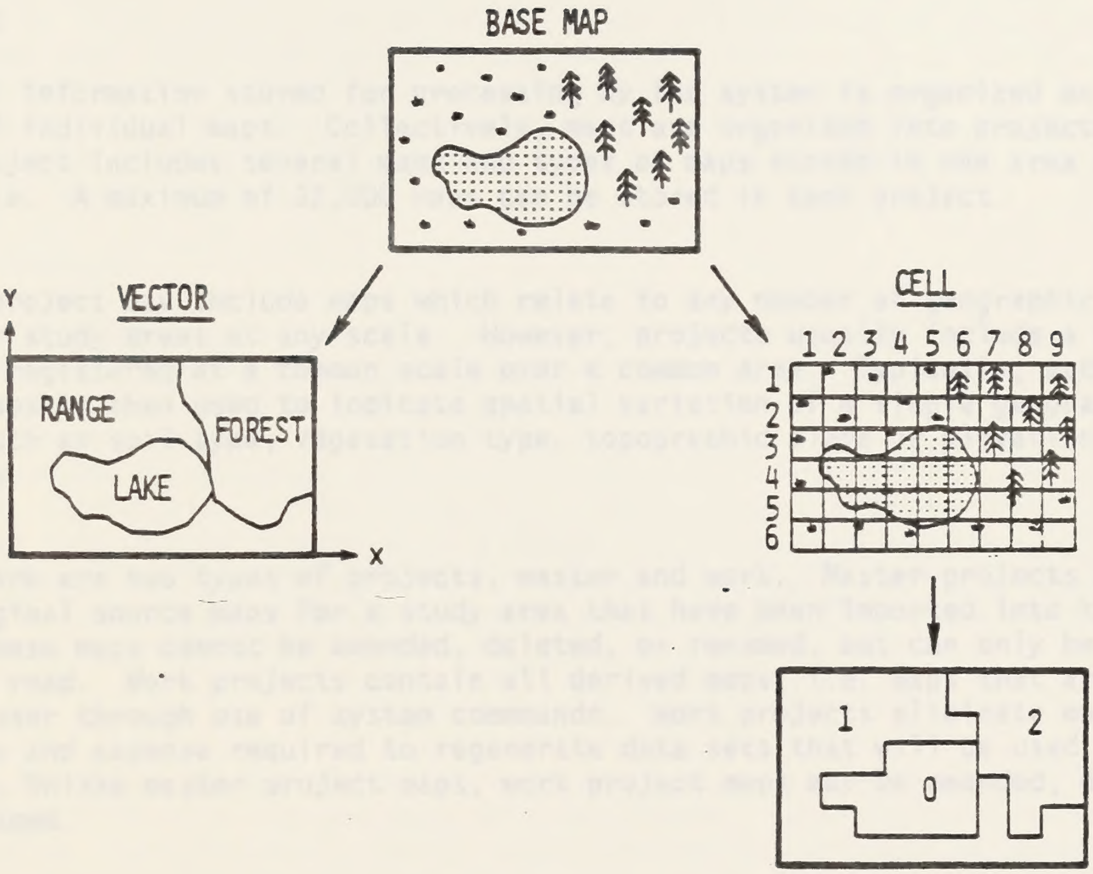

Figure 1. Data characterization in vector and cell format.

2. ORGANIZATION OF DATA

PROJECTS

All information stored for processing by the system is organized on the basis of individual maps. Collectively, maps are organized into projects. Each project includes several maps and types of maps stored in one area on a disk file. A maximum of 32,000 maps can be stored in each project.

A project may include maps which relate to any number of geographic regions or study areas at any scale. However, projects usually include a number of maps registered at a common scale over a common area. Typically, each of these maps is then used to indicate spatial variation of a single geographic theme such as soil type, vegetation type, topographic slope or elevation, or land use.

There are two types of projects, master and work. Master projects contain all original source maps for a study area that have been imported into the system. These maps cannot be amended, deleted, or renamed, but can only be accessed and read. Work projects contain all derived maps; i.e. maps that are made by the user through use of system commmands. Work projects eliminate much of the time and expense required to regenerate data sets that will be used repetitively. Unlike master project maps, work project maps may be amended, deleted, and renamed.

FILES

Master and work projects are stored as disk files in the operating system. When accessing the MOSS and MAPS software (Appendix A), the user must supply names of the disk files containing the desired projects. Master files are usually named after the study area they encompass. For example, WOLF, for USGS 7.5 min quadrangle Wolf Ridge, Colorado. However, for any given user there is only one work file, and this is called POLYGON. At any one time in a session a user may access one master file and his/her work file. Note that MOSS also contains a work file called CELL. This workfile specifically stores raster maps created within MOSS.

MAPS

Each map in a project includes several associated pieces of information; a name, a status indicator, a header, a type, subjects, and items. Each of these is described in the following paragraphs:

Names

A map name is a user-defined sequence of alphabetic, numeric, or symbolic characters unbroken by blank spaces. However, a map name must begin with at least one alphabetic character. Map names in MOSS may not exceed ten characters but may be up to sixteen characters in MAPS. Each map name is used to identify particular files and thereby serves to locate all information associated with the named map. Map names are assigned to each project as each new map is created and stored. Names cannot be assigned, modified, or deleted outside of the system. Each map name in a project must be unique and is usually an acronym which can be used to quickly identify it. For example, MDRWOLFRG, for mule deer ranges on Wolf Ridge, Colorado.

Status Indicators

A map status indicator is a letter which defines a map's status within MOSS or MAPS. Maps may be either protected (P), exposed (E), or archived (A). A protected map is one that can be accessed for processing only if that processing will leave the contents of the map unchanged. Master project maps are essentially "protected" although they have a status of E. Exposed maps may be updated, revised, overwritten, or erased at will. Work project maps are usually exposed although they may be protected or archived by the user at any time. An archived map is one which has been removed from disk (i.e. access by the system) and placed on an archival storage medium (e.g., a tape). When a new map is created its status is automatically set to E.

Headers

Information on the source, vintage, map projection, description, and characteristics of a map are kept in a map header. This information may be modified by the user and is useful when browsing the database to determine the suitability of a map for a particular analysis.

Types

Each map in a project has a number associated with it to indicate what type of map it is. Map types fall into four general groups; vector maps, cell maps, three-dimensional maps, and input/output files. Note that cell maps used for raster processing within MOSS are assigned differently.

Vector maps and their type numbers are:

1 - point
2 - line
3 - polygon

MAPS

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Status Indicators

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Types

Each map in a project has a number associated with it to indicate what type of map it is. Map types fall into four generic groups, vector maps, cell maps, transformed maps, and other output files. Some that will work with the spatial processing module MOSS are assigned differently.

Vector maps and their type numbers are:

1 = point
2 = line
3 = polygon

Point maps consist of single (x,y) coordinate pairs, for example, raptor nest sites. Line maps consist of series' of coordinates, for example, rivers. Polygon maps consist of closed series' of coordinates, for example, mule deer ranges.

Cell maps and their type numbers are:

6 - dichotomous
7 - discrete
8 - continuous

A dichotomous map is a map having cells depicting presence/absence, yes/no, +/-, etc... A discrete cell map is a map having a finite number of subjects which may be assigned to cells. A continuous cell map is a map having an infinite number of possible subjects, for example, an elevation map with elevations of 6402, 6402.1, 6402.11,... Note that various reclassification commands may be used to convert cell maps from one data type to another (see Chapter 3).

Three-dimensional maps and their type numbers are:

5 - elevation
11 - 3D point
12 - 3D line
13 - 3D polygon

Elevation maps consist of a sparse matrix of (x,y,z) coordinates used for grid interpolation, for example, rainfall gauging stations. Three-dimension (3D) maps are similar to their vector counterparts except that they have a third (z) coordinate.

Input/output files and their type numbers are:

10 - text
16 - write
17 - read
18 - display

Input/output "maps" consist of utilitarian work area files. Text files are true maps of prepared graphic text, for example, a word slide. Write files are files to which alphanumeric/text output may be written. Read files are files from which alphanumeric/text input may be read. Display files are files to which graphics output may be sent.

Subjects

Based on its characteristics, each feature or cell in a map is assigned an identifying attribute called a subject. For example, a map of vegetation types might consist of three subjects; forest, shrubs, and meadows. Subjects are the measured attributes which a map associates with specific geographic locations, i.e., the items in a conventional map legend.

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For vector maps, subjects are 30 character (or less) alphabetic or numeric strings. Subjects are assigned to features when the map is digitized. Usually, subject names are chosen which describe the feature in a self explanatory manner (e.g., WINTER RANGE for polygons of mule deer winter range) although they may be from a classification scheme (e.g., 411AS for closed-canopy deciduous aspen forest).

For cell maps, each cell in the map is assigned a subject, also called a value. Values are assigned when the map is initially encoded or rasterized, and are stored as real numbers between -10,000,000 and 10,000,000. It is only this numerical value which is actually processed by most of the system's operations. As numbers, they may represent actual values or serve simply as non-quantitative identifiers or codes. For example, a value of 10.0 might be used to represent areas at ten feet above sea level or it might simply represent the tenth vegetation type recorded (e.g., pinyon forest). When used as identifiers for discrete maps, it is suggested that values be assigned as a consequtive sequence of positive integers beginning with 1, and that 0 be reserved to represent a null subject (e.g., dry land on a map of water bodies). Discrete map cells which do not have a subject are treated mathematically as zero but are assigned a value of "background". Note that a discrete map cannot contain more than 32,000 unique subjects or values. A map of only one subject, and therefore only one value, is referred to as a constant cell map. A dichotomous map has two subjects, presence and absence, which are always assigned values of 1 and 0, respectively. Discrete cell values may be assigned an identifying label. This label is generated by several processing operations and is typically a descriptor of the cell value's subject. Labels may be up to 64 characters long and need not be unique. Cell values do not have to be labeled, and labels may be assigned or redefined at any time.

Some data structures (e.g., forest inventories) have multiple descriptors for each feature. The Multiple Attributes Database allows the user to assign several discrete attributes or subjects for any point, line, or polygon. For example, a stand of pinyon pine forest represented on a polygon map of forest types might have several important measurements or characteristics associated with it; percent canopy cover, downed fuel load, understory diversity, snags per acre, age of stand, seed production, etc... Accessory information such as these are called multiple attributes. Cell maps may also have multiple attributes or values. Currently, multi-value cell maps are only handled by the raster processing capabilities of MOSS.

Items

A map item or feature is the smallest unit comprising the map. For a point map this is a single (x,y) coordinate; for a line map this is a discrete line segment; for a polygon map this is a closed array of line segments; and for a cell map this is an individual cell. Each item in a vector map is assigned a unique identifying number. Each item in a cell map is represented by a pair of integer coordinates which uniquely identify a row-column position on the cell grid. Coordinates are defined with respect to an origin in the upper left corner of each map. Cell dimensions, and therefore number of rows and columns,

For vector maps, subjects are 20 character (or less) alphanumeric or numeric (names). Subjects are assigned to features when the map is digitized. Usually, subject names are chosen which describe the feature in a self explanatory manner (e.g., RIVER BANK for polygons of male deer winter range) although they may be from a classification scheme (e.g., 9145 for single-canopy Cottonwood Aspen forest).

For cell maps, each cell in the map is assigned a subject, also called a value. Values are assigned when the map is initially encoded or rasterized, and are stored as real numbers between -10,000,000 and 10,000,000. It is only this numerical value which is actually processed by most of the system's operations. As numbers, they can represent actual values or serve simply as non-quantitative (nominal) codes. For example, a value of 10.0 might be used to represent areas of 10% tree cover (a value), or it might simply represent the tenth vegetation type recorded (e.g., aspen forests). When used as identifiers for discrete maps, it is suggested that values be assigned as a consecutive sequence of whole integers beginning with 1, and that 0 be reserved to represent a null subject (e.g., dry land on a map of water bodies). Discrete map cells which do not have a subject are treated analytically as zero and are assigned a value of "background". Note that a discrete map cannot contain more than 32,767 unique subjects or values. A map of only one subject, and therefore only one value, is referred to as a constant cell map. A dichotomous map has two subjects, presence and absence, which are always assigned values of 1 and 0, respectively. Discrete cell values may be assigned an identifying label. This label is maintained by several processing operations and is useful as a description of the cell value's subject. Labels can be up to 40 alphanumeric long and need not be unique. Cell values do not have to be labeled, and labels may be assigned or modified at any time.

Some data structures (e.g., forest inventories) have multiple descriptions for each feature. The Multiple Attribute Database allows the user to assign several discrete attributes or subjects for any point, line, or polygon. For example, a stand of single-crown forest represented by a polygon map of forest types might have several important measurements or characteristics associated with it: dominant canopy species, diameter, basal area, understory diversity, crown cover class, site productivity, etc. [illegible] and other descriptive attributes. Cell maps may also have multiple attributes or values. Currently, multiple-value cell maps are only handled by the vector processing capabilities of MOSS.

[illegible]

[illegible]

are specified when a map is rasterized. A cell map cannot contain more than 32,000 rows or columns nor more than 10,000,000 total items. Cell maps used in MOSS may not have more than 1,024 rows or columns. Note that all maps to be used together must have the same cell size and the same number of rows and columns.

Cell size defines geographic distance in units of cartographic distance of one grid space. A grid space is the distance between the centers of any two horizontally or vertically (as opposed to diagonally) adjacent grid-cells. Cell size is expressed in units of distance (meters or feet) or in units of area (hectares or acres).

DATA MANIPULATION

Once the database is accessed, MOSS and MAPS provide the capability to browse the database and to retrieve all or parts of it. Browsing the database is used to determine the suitability of a map for a particular analysis. The hierarchical nature of data organization described above facilitates its retrieval from the database. Data browsing and retrieval are discussed in more detail in the following paragraphs.

Browsing

The primary piece of information by which a map is identified is its name. All cartographic processing is done on a map-by-map basis and the map name serves to identify all data associated with that map. Once a map has been identified by its name, auxiliary information concerning the map's content may be accessed. This includes map status, header information, map type number, subject list, and number of items. The hierarchy associated with a map is a function of inherent complexity of the map and specifications provided at the time data were digitized or rasterized.

Retrieving

The hierarchical nature of data organization allows all, or a specific portion, of a map to be retrieved (Fig. 2). Usually, only a portion of data in a map file is needed for any given analysis. At the map level, one specific subject or item may be retrieved and all others avoided. This increases the effectiveness of data analysis by allowing the user to avoid unwanted detail or extraneous data. It also increases the efficacy of data processing because less data is handled. When an existing map is specified for processing, it is convenient to think of the information associated with the map as being copied from the map file on disk to the user's access or work area (Fig. 3). New data generated as a result of processing is then written back to, and stored in, the user's work project. In as much as existing information is "copied" before reading for processing, it can be used repeatedly without being modified or destroyed. MOSS, maps which are retrieved are called "active" maps and are catalogued in an active map table. Each entry in the table is assigned a unique identifying number called the map ID, active ID, or data set ID. Some commands which create new maps automatically activate the maps. However, this data will not be automatically stored in the work project and must be specifically saved.

re specified when a map is rasterized. A cell map cannot contain more than 4,000 rows or columns nor more than 10,000,000 total items. Cell maps used in MIS analysis have more than 1,000 rows or columns. Note that all maps to be used together must have the same cell size and the same number of rows and columns.

Cell size defines geographic distance in units of cartographic distance of the grid space. A grid space is the distance between the centers of any two horizontally or vertically (as opposed to diagonally) adjacent grid-cells. Cell size is expressed in units of distance (meters or feet) or in units of area (hectares or acres).

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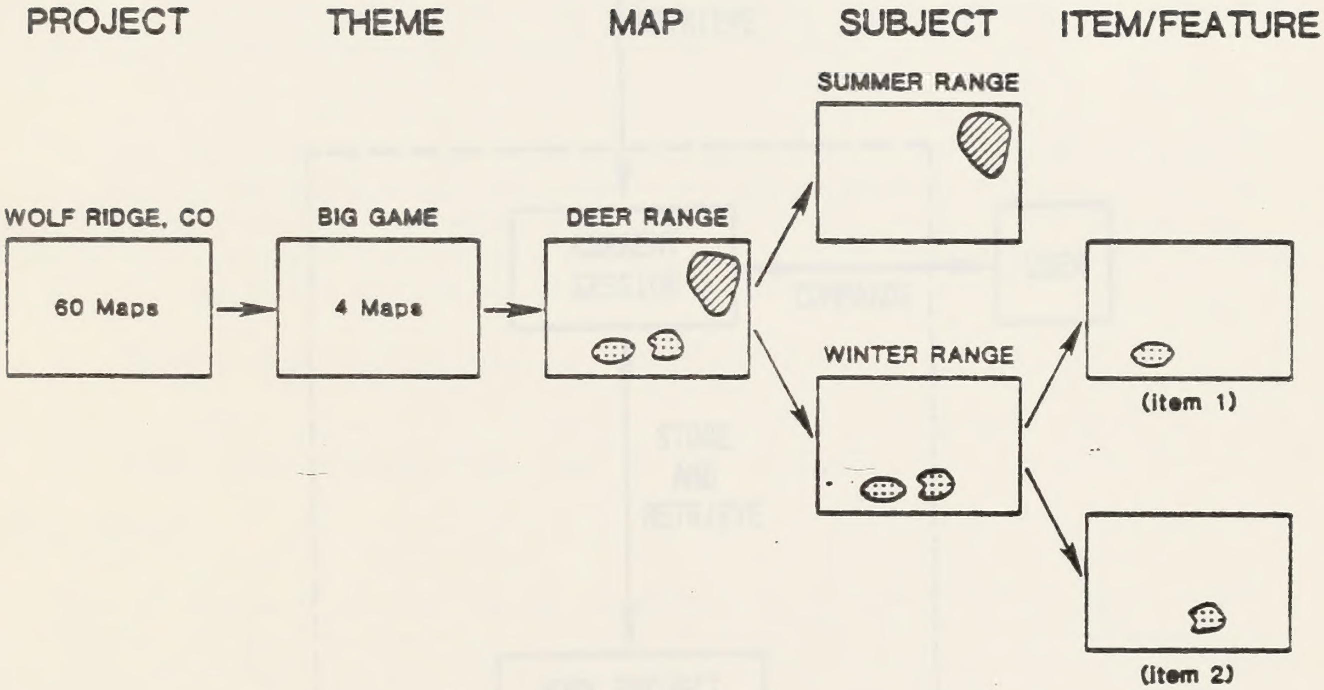


Figure 2. Hierarchy and retrieval of a polygon map.

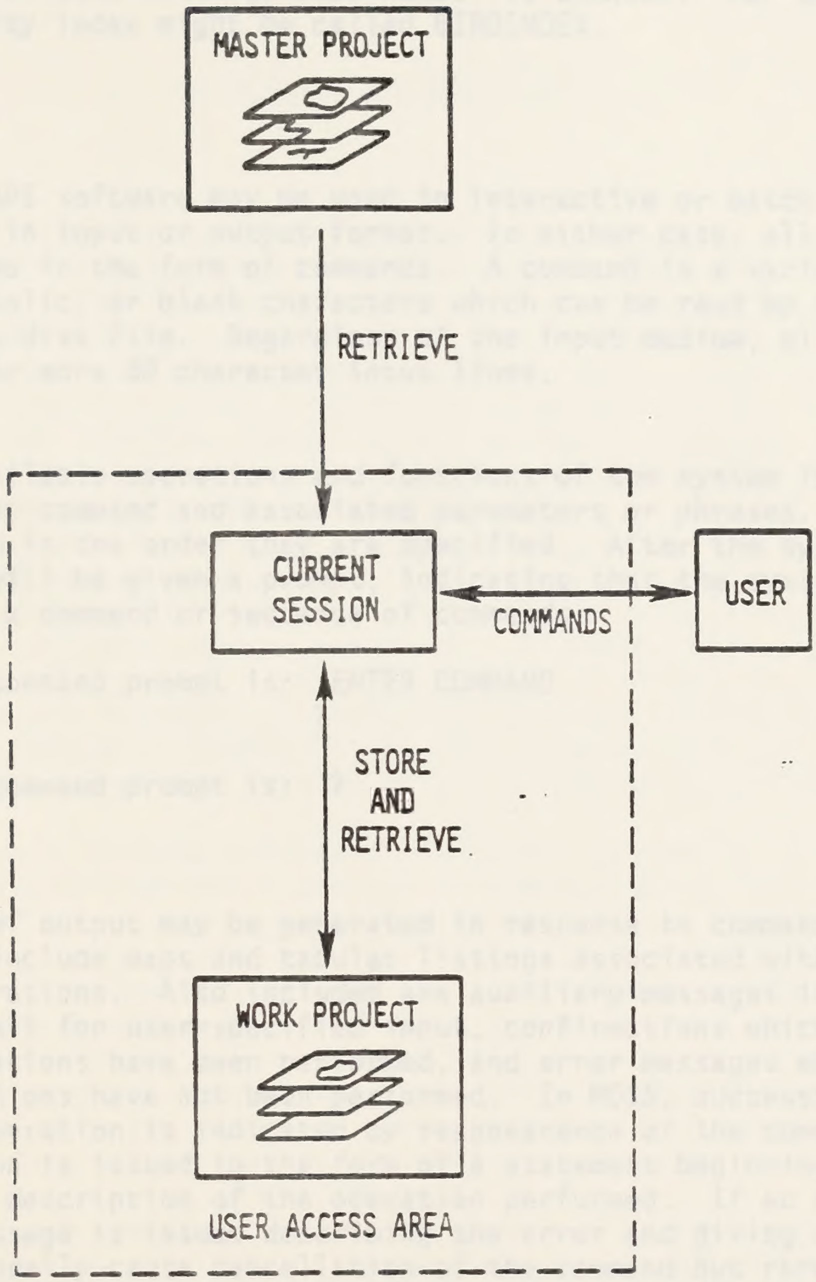


Figure 3. Data storage and retrieval.

Maps with a multiple attributes database are accompanied by three pieces of information used as the basis for database browsing and retrieval. These are: a unique numerical I.D. for each attribute, a ten character or less keyword for each attribute, and a 60 character or less description of each attribute. The keyword is typically an acronym which can be used to quickly identify a particular attribute when its I.D. number is unknown. For example, a bird species diversity index might be called BIRDINDEX.

USER INPUT

The MOSS and MAPS software may be used in interactive or batch mode with little or no change in input or output format. In either case, all user-specified input is entered in the form of commands. A command is a string of alphabetic, numeric, symbolic, or blank characters which can be read by the system from a terminal or a disk file. Regardless of the input medium, all commands are made up of one or more 80 character input lines.

Each of the available operations and functions of the system is invoked by its own particular command and associated parameters or phrases. All operations are performed in the order they are specified. After the system is accessed, the user will be given a prompt, indicating that the system is ready to read and process a command or sequence of commands.

For MOSS, the command prompt is: ENTER COMMAND
?

For MAPS, the command prompt is: ?

SYSTEM OUTPUT

Several forms of output may be generated in response to commands. Most importantly, these include maps and tabular listings associated with display and description operations. Also included are auxiliary messages in the form of; prompts which call for user-specified input, confirmations which indicate that specified operations have been performed, and error messages which tell why specified operations have not been performed. In MOSS, successful completion of a command operation is indicated by reappearance of the command prompt. In MAPS, confirmation is issued in the form of a statement beginning with "OK" followed by a brief description of the operation performed. If an error occurs, an error message is issued describing the error and giving an error number. Errors generally cause cancellation of the command but rarely cause termination of the session. User-oriented output may be directed to the log-on console, to a write or display disk file in the user's work area, or to a second auxilary terminal (also known as two terminal mode).

Maps with a multiple attribute database are accompanied by three pieces of information used as the basis for database browsing and retrieval. These are a unique numerical I.D. for each attribute, a six character or less identifier for each attribute, and a 40 character or less description of each attribute. The keyword is basically an acronym which can be used to quickly identify a particular attribute when the I.D. number is unknown. For example, a red species diversity map might be called SPDIVRED.

USER INPUT

The MOSS and MAPS software may be used in interactive or batch mode with little or no change in input or output format. In either case, all user-specified input is entered in the form of commands. A command is a string of alphabetic, numeric, symbolic, or blank characters which can be read by the system from a terminal or a disk file. Regardless of the input medium, all commands are made up of one or more 80 character input lines.

Each of the available operations and functions of the system is invoked by one particular command and associated parameters or options. All operations are performed in the order they are specified. After the system is accessed, the user will be given a prompt, indicating that the system is ready to accept and process a command or sequence of commands.

For MOSS, the command prompt is: ENTER COMMAND
?

For MAPS, the command prompt is: ?

SYSTEM OUTPUT

Several forms of output may be generated in response to commands. Most prominently, these include maps and tabular listings associated with display and descriptive operations. Also included are auxiliary messages in the form of prompts which call for user-specified input, confirmations which indicate that specified operations have been performed, and error messages which tell that specified operations have not been performed. In MOSS, successful completion of a command operation is indicated by re-appearance of the command prompt. In MAPS, confirmation is issued in the form of a statement beginning with "OK" followed by a brief description of the operation performed. If an error occurs, an error message is issued describing the error and giving an error number. Errors generally cause cancellation of the command but rarely cause termination of the session. User-oriented output may be directed to the user terminal, to a print or display disk file in the user's work area, or to a second auxiliary terminal (also known as the terminal mode).

3. PROCESSING CAPABILITIES

Data processing capabilities of the software are organized as a series of individual operations which are functionally independent but which may be applied together. By controlling the order in which these operations are executed, and by using the database to store results of each operation for subsequent processing, a variety of more complex analyses can be constructed. Operations which make up the system are identified by name in the form of commands. These names are sometimes contrived but attempt to suggest the nature of each operation. Note that some command names are duplicated by MOSS and MAPS and that they may perform different operations.

Commands can be classified into five functional groups. These are: program control, data manipulation, data display, data description, and data analysis. The latter may be further subdivided into four functional classes: reclassify, overlay, distance, and neighborhood. Although other classification schemes are possible, this scheme serves the purpose of orienting the user to the underlying logic and functions of individual commands. Table 1 lists MOSS commands grouped by function. Table 2 lists MAPS commands grouped similarly. Each of these groups is described briefly in the following paragraphs:

Program Control: These commands provide an interface between MOSS and MAPS and the computer operating system and/or provide information about MOSS or MAPS itself.

Data Manipulation: These commands provide the capability to add to, access, and manipulate the map database.

Data Display: These commands provide the capability to produce user-oriented output in the form of data set displays. Display may be on a graphics CRT, an alphanumeric CRT, a line printer, or on a plotting device such as a Calcomp.

Data Description: These commands produce user-oriented output in the form of data set parameter reports and tables. These commands can calculate area, distance, perimeter, length, frequency, descriptive statistics such as mean and range, and location coordinates. They can also describe feature information and produce a listing of active data sets.

Data Analysis: These commands provide for descriptive analysis of map data sets and for the generation of new map data sets by transformation of existing maps. Each of these commands may be characterized as belonging to one of four classes according to the way in which it addresses the thematic and/or spatial content of a map. These classes function to:

-- reclassify maps,
-- overlay maps,
-- measure cartographic distance, and
-- characterize cartographic neighborhoods.

-- Reclassify: Data reclassification commands involve the creation of new maps by reassigning values of existing maps. These commands can select data sets based on attribute information, feature size or length, or a random selection of features. A typical vector example of this class of operations is illustrated in Figure 4. A typical cell example is illustrated in Figure 5.

Table 1. Functional groups of MOSS commands.

Program Control:	BAUD, BUTTON, BYE, CLI, COMMANDS, COST, DEVICE, HELP, MAPS, NEWS, OPEN, PAGE, STATUS, TERMINAL, UTILITY
Data Manipulation:	ADD, ARCHIVE, *CONTOUR, DEARCHIVE, DELETE, DIGITIZE, DIVIDE, EDITATT, EXPORT, FREE, GENERATE, LIST, MERGE, MOVELABEL, *MULTIVAL, *POLYCELL, *POLYMVG, PROJECTION, SAVE, *SNGVAL, *SPSS, TEXT, TRANSLATE, WEED
Data Display:	ASSIGN, CALCOMP, ERASE, FLOOD, *GCONTOUR, LEGEND, LINE, NUMBER, PLOT, *PROFILE, RESET, SHADE, SHOW, SYMBOL, TESTGRID, *THREED, WINDOW, ZOOM
Data Description:	ACTIVE, AREA, AUDIT, DESCRIBE, DISTANCE, FREQUENCY, LENGHT, LOCATE, PERIMETER, QUERY, REPORT, STATISTICS
Data Analysis:	
(Reclassify)	BSEARCH, COMPUTE, SAMPLE, SELECT, SIZE
(Overlay)	*COMPOSITE, GOVERLAY, LPOVER, *MODELG, OVERLAY
(Distance)	BUFFER, CONTIGUITY, EDGE, PROXIMITY
(Neighbor)	*ASPECT, *GRID, *SLOPE

* denotes raster capabilities (see Appendix F)

Table 2. Functional groups of MAPS commands.

Program Control:	BAUD, BYE, CLOSE, COST, DISPLAY, EXPLAIN, INFORM, NEWS, OPEN, PAGE, READ, WRITE
Data Manipulation:	ARCHIVE, CONSTANT, COPY, DEARCHIVE, DELETE, EXPOSE, IMPORT, LABEL, LIST, PROTECT, RASTERIZE, RENAME
Data Display:	3D, CONTOUR, ERASE, NOTE, PLOT, PRINT, RESET, SHADE, VIEW, WINDOW, ZOOM
Data Description:	AREA, DESCRIBE, QUERY
Data Analysis: (Reclassify)	AGGREGATE, CATEGORIZE, CUT, EXTRACT, FUNCTION, ISOLATE, MERGE, RENUMBER, SIZE, SLICE
(Overlay)	ADD, AVERAGE, BOOLEAN, COVER, CROSS, DIVIDE, EXPONENTIATE, INTERSECT, MATH, MAXIMIZE, MINIMIZE, MULTIPLY, SCORE, SUBTRACT
(Distance)	PROXIMITY, ZONE
(Neighbor)	ASPECT, SCAN, SLOPE, VISTA

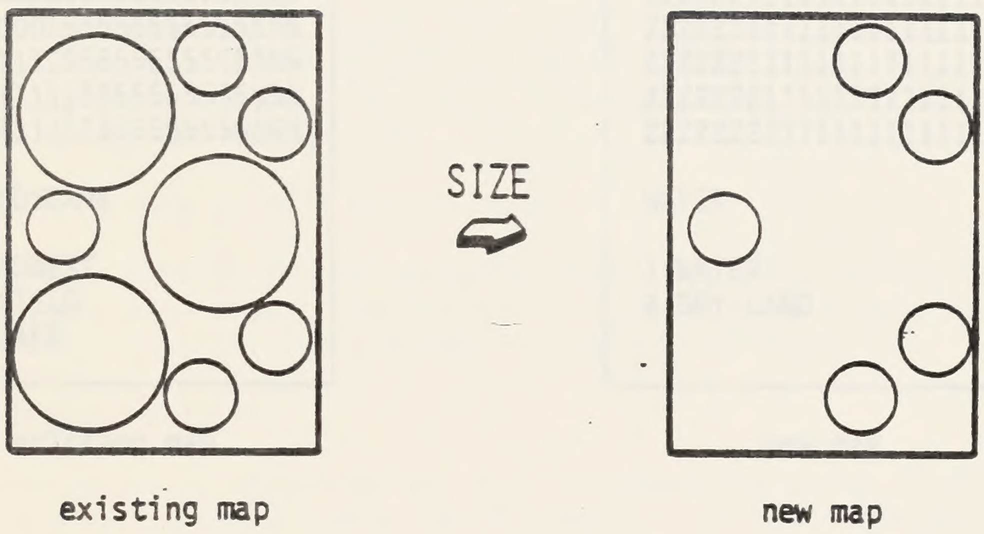


Figure 4. Example of reclassifying vector map subjects.

RENUMBER LANDSCAPE FOR WATER ASSIGNING 2 TO 0 ASSIGNING 2 TO 1 , ASSIGNING 1 TO 5

```
0000000005555555555
0000000055555555555
0000000555555555555
0000005555555555555
0000055555555555555
1111155555555555555
1111115555555555555
1111111555555555555

LANDSCAPE

0 FOREST
1 FIELD
5 LAKE
```

existing map

```
2222222221111111111
2222222211111111111
2222222111111111111
2222221111111111111
2222211111111111111
2222221111111111111
2222222111111111111
2222222211111111111

WATER

1 WATER
2 DRY LAND
```

new map

Figure 5. Example of reclassifying cell map values.

-- Overlay: Overlay analysis commands involve the creation of new maps computed as a function of location on two or more existing maps. These commands can perform mathematical combinations or the Boolean operations of intersection, non-intersection, and union. A typical vector example of this class of operations is illustrated in Figure 6. A typical cell example is illustrated in Figure 7.

-- Distance: Distance analysis commands relate primarily to spatial characteristics of map data. These commands can create new maps based on distance, proximity, and contiguity. A typical vector example of this class of operation is illustrated in Figure 8. A typical cell example is illustrated in Figure 9.

-- Neighborhood: Neighborhood analysis commands involve the creation of new maps computed as a function of surrounding locations. These commands can create maps of topographic slope and aspect, and compute a variety of "roving window" statistics. All operations of this class are performed on raster data. A typical example of this class of operations is illustrated in Figure 10.

A TYPICAL SESSION

The following sequence of steps provide the user with an overview of the general procedures common to most MOSS and MAPS sessions. Figure 11 illustrates this general approach and sequence. For more detail the user may refer to specific descriptions of commands.

Step 1: Connect to MOSS or MAPS and the data

Once the user logs on to the operating system MOSS and/or MAPS may be accessed (Appendix A). When a new session is begun, the user must open a master project database. In MOSS, the previous session may be restarted.

Step 2: Browse the database

The next step is to determine the type and characteristics of the maps stored in the data files. Browsing the database is important for two reasons, to determine the suitability of maps for analysis and to provide a precise description of maps.

Step 3: Retrieve the desired data

Before the user can display or analyze any data set, it must be retrieved. This is analogous to creating a local copy of the map. In MOSS, data which has been retrieved is referred to as active data.

Step 4: Define the viewing window

Before any map can be analyzed or displayed the user must set the display window. This indicates the area of interest or viewing window on the earth's surface.

-- Overlay. Overlay analysis commands involve the creation of new maps computed as a function of location in two or more existing maps. These commands are performed on coordinates of the spatial intersections, intersections, and unions. A typical vector example of this class of operations is illustrated in Figure 6. A typical cell example is illustrated in Figure 7.

-- Distance. Distance analysis commands relate primarily to spatial characterization of map data. These commands can create new maps based on distance, geometry, and contiguity. A typical vector example of this class of operation is illustrated in Figure 8. A typical cell example is illustrated in Figure 9.

-- Neighborhood. Neighborhood analysis commands involve the creation of new maps as a function of surrounding locations. These commands can calculate many of important slope, and aspect, and compute a variety of "moving window" statistics. All operations of this class are performed on raster data. A typical example of this class of operations is illustrated in Figure 10.

TYPICAL SESSION

The following sequence of steps presents the outline of a typical session of the potential commands common to both MOSS and MAPS sessions. Figure 11 illustrates a general approach and sequence. For more detail, the user may refer to specific documentation and commands.

Step 1. Connect to MOSS or MAPS and the data

Once the user logs on to the operating system, MOSS and/or MAPS may be accessed (Appendix A). When a new session is begun, the user must also open a workfile directory. If not, the previous session may be restarted.

Step 2. Browse the database

The next step is to determine the type and character of the maps of the data files. Browsing the database is important for two reasons, to determine the availability of maps for analysis and to identify a specific collection of maps.

Step 3. Structure the analysis data

Before the user can manipulate or analyze any data set, it must be retrieved from storage or create a local copy of the maps. In MOSS, data which has been retrieved is referred to as active data.

Step 4. Define the viewing window

Before any data can be analyzed or displayed the user must set the appropriate window. This defines the area of interest and allows for a subset of the overall database.

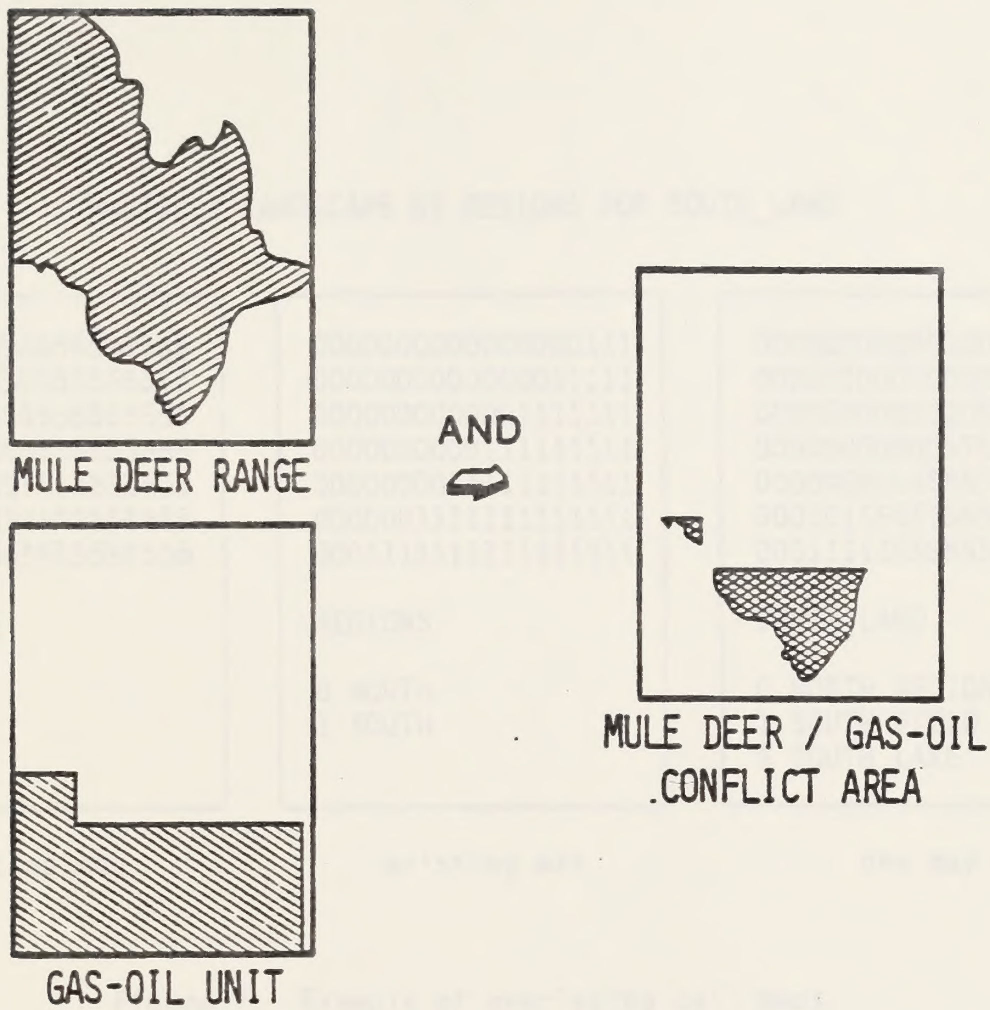


Figure 6. Example of overlaying vector maps.

MULTIPLY LANDSCAPE BY REGIONS FOR SOUTH_LAND

```
0000000005555555555
0000000055555555555
0000000555555555555
0000005555555555555
0000055555555555555
1111115555555555555
1111111555555555555

LANDSCAPE

0 FOREST
1 FIELD
5 LAKE
```

existing map

```
0000000000000000111
0000000000000011111
0000000000001111111
0000000000111111111
0000000011111111111
0000001111111111111
0001111111111111111

REGIONS

0 NORTH
1 SOUTH
```

existing map

```
0000000000000000555
0000000000000055555
0000000000005555555
0000000000555555555
0000000005555555555
0000011555555555555
0001111555555555555

SOUTH_LAND

0 NORTH REGION
1 SOUTH FIELD
5 SOUTH LAKE
```

new map

Figure 7. Example of overlaying cell maps.

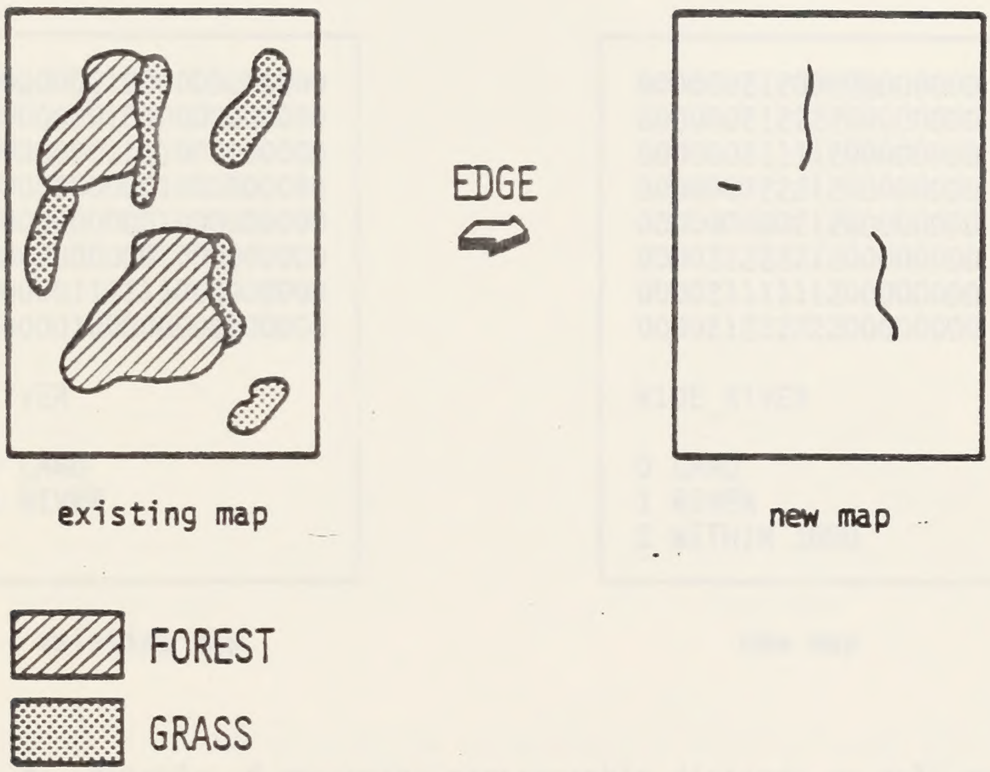


Figure 8. Example of measuring cartographic distance on vector maps.

ZONE RIVER INTO 1 TO 1000 FOR WIDE_RIVER

```
00000001000000000000
00000001000000000000
00000001111000000000
00000000001000000000
00000000001000000000
00000000001000000000
00000111111000000000
00000100000000000000

RIVER

0 LAND
1 RIVER
```

existing map

```
00000021200000000000
00000021222200000000
00000021111200000000
00000022221200000000
00000000021200000000
00002222221200000000
00002111111200000000
00002122222200000000

WIDE_RIVER

0 LAND
1 RIVER
2 WITHIN 1000
```

new map

Figure 9. Example of measuring cartographic distance on cell maps.

SCAN LANDSCAPE DIVERSITY FOR LAND_MIX

```
00000000055555555555
00000000555555555555
00000005555555555555
00000055555555555555
00000555555555555555
11111155555555555555
11111115555555555555

LANDSCAPE

0 FOREST
1 FIELD
5 LAKE
```

existing map

```
11111111221111111111
11111112211111111111
11111122111111111111
11111221111111111111
22223311111111111111
11111122111111111111
11111112211111111111

LAND_MIX

1 ONE TYPE NEARBY
2 TWO TYPES NEARBY
3 THREE TYPES NEARBY
```

new map

Figure 10. Example of characterizing cartographic neighborhoods on cell maps.

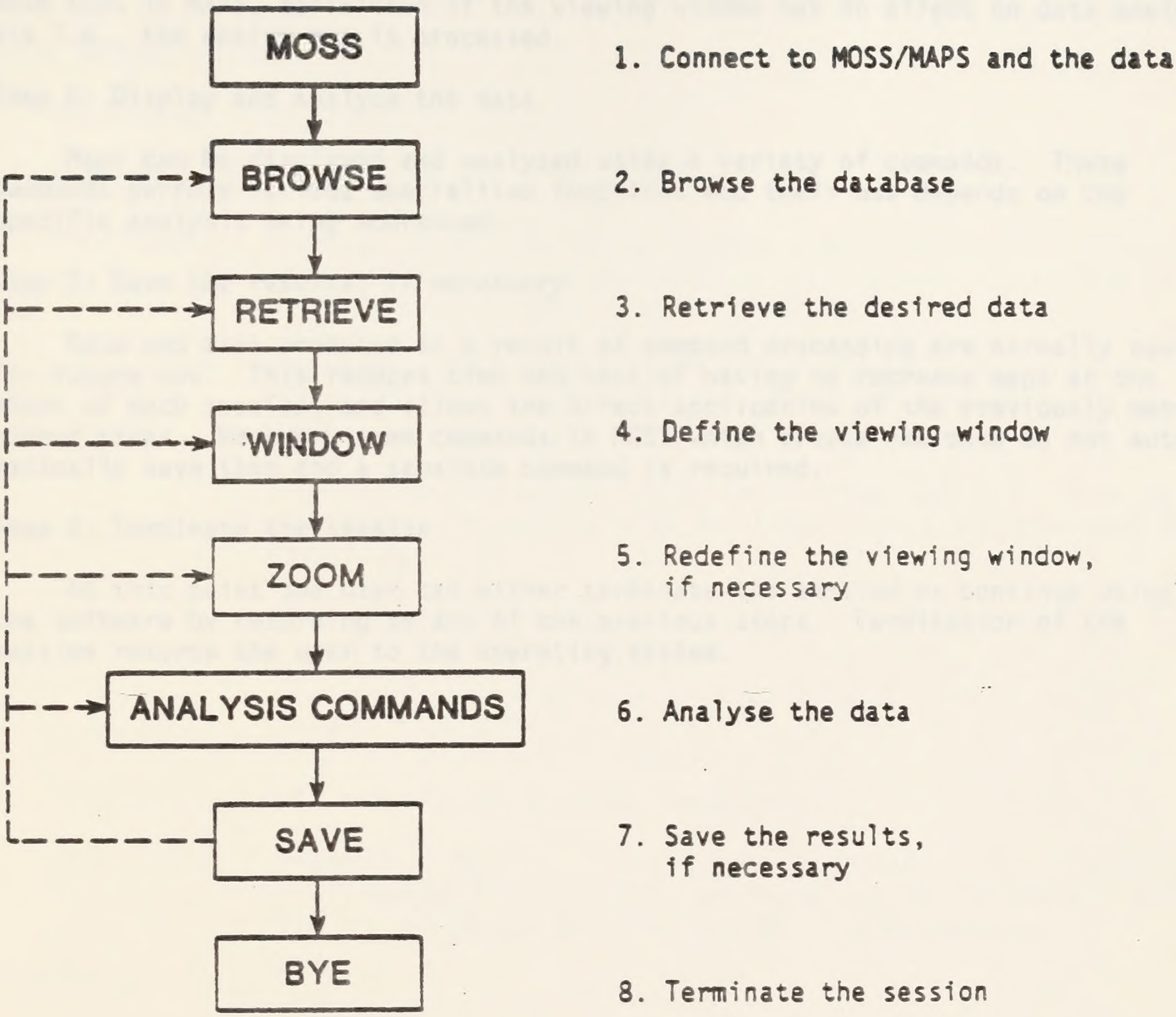


Figure 11. Eight steps in a typical session.

Step 5: Redefine the display window, if necessary

Frequently, only a certain portion of a study area is relevant to the user's analysis. The display window may be redefined to enclose the specific area of interest. There are several advantages to this; the display is magnified for greater detail and resolution, less data will be plotted thus reducing plot time, and cost of execution is reduced because less data is processed. Note that in MAPS, definition of the viewing window has no effect on data analysis i.e., the entire map is processed.

Step 6: Display and analyze the data

Maps can be displayed and analyzed using a variety of commands. These commands perform various specialized functions and their use depends on the specific analysis being addressed.

Step 7: Save the results, if necessary

Data and maps produced as a result of command processing are normally saved for future use. This reduces time and cost of having to recreate maps at the start of each session, and allows the direct application of the previously mentioned steps. However, some commands in MOSS which create new data do not automatically save them and a separate command is required.

Step 8: Terminate the session

At this point the user can either terminate the session or continue using the software by returning to any of the previous steps. Termination of the session returns the user to the operating system.

Step 5: Redefine the display window, if necessary

Frequently, only a certain portion of a study area is relevant to the user's problem. The display window may be redefined to enclose the specific area of interest. There are several advantages to this. The display is magnified for enhanced detail and resolution, less data will be plotted thus reducing plot times, and cost of execution is reduced because less data is processed. Note that in MAPS, definition of the viewing window has no effect on data analysis i.e., the entire map is processed.

Step 6: Display and analyze the data

Maps can be displayed and analyzed using a variety of commands. These commands perform various specialized functions and their use depends on the specific analysis being performed.

Step 7: Save the results, if necessary

Data and maps produced as a result of command processing are normally saved for future use. This reduces time and cost of running in increments at the start of each session, and allows the direct modification of the previously generated ones. However, some commands in MAPS which create new data do not automatically save them and a separate command is required.

Step 8: Terminate the session

At this point the user can either terminate the session or continue using the software by returning to any of the previous steps. Termination of the session returns the user to the operating system.

GIS IN THE BLM

HARDWARE, IMPLEMENTATION, and a PARTIAL LIST OF CURRENT GIS PROJECTS

ALASKA STATE OFFICE

HARDWARE: MV10000

IMPLEMENTATION: no plan

PROJECTS: McGrath Resource Area - all land coverage for use in environmental assessment, oil and gas leasing, wildlife and subsistence studies.

Peninsula Resource Area - oil and gas leasing, and wildlife and subsistence study in the Kvichak Study Area.

Fairbanks District Office - testing for the Henry llotment, reindeer and caribou range study, and snow modeling.

Fire Fuels Mapping

ARIZONA

HARDWARE: C330

IMPLEMENTATION; Draft, awaiting approval

PROJECTS: Arizona Strip District Office - digitizing wilderness boundaries, working on landstatus, soils, DEM's, transportation, range improvement.

CALIFORNIA

HARDWARE: M600

IMPLEMENTATION: Forming user committee

PROJECTS: Ukiah planning amendment - digitizing 6 quadrangles with multiple themes, beginning data analysis.

Inyo R.A. - California Desert Project, digitizing 108 quadrangles, multiple themes.

Sacramento - minerals work on gravel quarry project, beginning data analysis.

Ongoing - digitizing BLM boundaries and ownership for fire program.

COLORADO

HARDWARE: MV6000

IMPLEMENTATION: Preparing strategy

PROJECTS: Green River Hams Fork Coal EIS - a re-delineation of tracts by Regional Coal Team; FY 1985 data entry for approximately 40 7.5 minute quadrangles, in conjunction with Wyoming.

Uncompagre RMP - data entry during FY 1985 for approximately 60 7.5 minute quadrangles; data analysis to follow in FY 1986.

C-A Tract 3D disposal pile modeling in FY 1985.

IDAHO

HARDWARE: Dial-up to Colorado State Office MV8000

IMPLEMENTATION: Plan in draft form

PROJECTS: Boise District Office - digitizing soils information in conjunction with SCS.

Birds of Prey project in analysis stage.

FY 1986, digitize Owyhee Resource Area.

Apply GIS to possible alternatives in Cascade RMP.

Proposed applicationf or agricultural trespass on BLM lands, using Landsat and MOSS.

MONTANA

HARDWARE: DG 20

IMPLEMENTATION: Preparing first draft.

PROJECTS: Powder River Basin Coal Project in conjunction with Wyoming.

NEVADA

HARDWARE: Dial-up to DSC

IMPLEMENTATION: Preparing first draft.

PROJECTS: Soil Landscape Analysis Project (SLAP).

Wildlife habitat study project for bighorn sheep, for subsequent establishment of statewide criteria.

Planning for mining and drilling leases.

Conversion of fire fuels map data and historical occurrances to MOSS format.

NEW MEXICO

HARDWARE: M600

IMPLEMENTATION: Preparing strategy

PROJECTS: Rio Puerco R.A. - wilderness analysis reports, including maps of all 12 wilderness areas, using vegetation, soil, ownership, and area information.

Farmington R.A. - digitizing data for RMP, including range improvements, range allotments, soils, vegetation.

Landsat study, area and length analyses, conflict analysis using MAPS, wilderness analysis, and maps of all areas and themes.

Roswell R.A. - automate oil and gas panel maps for 354 quadrangles, including landlines, surface and mineral rights, unitization agreements, and PI data for oil and gas wells.

White Sands R.A. - RMP, including landlines, ownership, vegetation, range, habitat, wilderness boundaries, transportation, cultural resources, DEMs, maps of all areas, and analysis including acreage, frequency, distance, proximity, and length.

Las Cruces/Lordsburg R.A. - digitizing for grazing activity plans.

Socorro R.A. - data preparation for RMP, including wilderness reports.

State Office Scientific Systems - statewide wilderness EIS with minerals conflicts; digitizing 300 master title plats for 10 overlays for Native American case of land ownership.

Minerals Department - coal and oil and gas isopach map.

OREGON

HARDWARE: C330

IMPLEMENTATION: None in progress

Planning for mining and drilling leases.

Conversion of [illegible] map data and [illegible] attributes to [illegible] format.

NEW MEXICO

HARDWARE: [illegible]

IMPLEMENTATION: [illegible]

PROJECTS: Rio Puerco R.A. - wilderness analysis [illegible] including areas of all 12 wilderness areas, [illegible] vegetation, soil, [illegible], and [illegible]

[illegible] - digitizing data for [illegible] including [illegible] range [illegible], [illegible] vegetation.

[illegible], acre and [illegible] analyses, [illegible] analysis using [illegible], wilderness analysis, and [illegible] of all areas and [illegible].

[illegible] - [illegible] oil and gas [illegible] [illegible] including [illegible], [illegible] mineral rights, [illegible] agreements, and [illegible] for oil and gas wells.

[illegible] R.A. - [illegible] including [illegible] vegetation, range, [illegible], wilderness, [illegible], [illegible] [illegible] [illegible] of all areas, and analysis [illegible] frequency, distance, [illegible], and [illegible]

[illegible] R.A. - digitizing [illegible] plans.

[illegible] R.A. - [illegible] for [illegible] wilderness [illegible].

[illegible] - [illegible] [illegible] [illegible] [illegible] [illegible].

[illegible] - [illegible] oil and gas [illegible] data.

[illegible]

[illegible]

[illegible]

PROJECTS: Burns Project - range project in S.E. Oregon, including soils, vegetation, range types.

State of Oregon minerals map, 1:500000

FY 1986 - Roseburg Orthophoto DEM project, Lakeview soils project to be digitized.

UTAH

HARDWARE: Dial-up to Colorado State Office MV8000

IMPLEMENTATION: Completed implementation plan FY 1985.

PROJECTS: Book Cliffs R.A. - initial database building, digitizing, some analysis on tar sands project, approx. 65 quadrangles.

Ongoing: digitizing State of Utah 1:500000 various themes.

Ongoing: Utah County, digitized as one map at 1:100000

FY 1986 - San Rafael R.A., begin digitizing for RMP

WYOMING

HARDWARE: M600

IMPLEMENTATION: Preparing strategy

PROJECTS: Pinedale R.A. - activity planning for forestry, range, oil and gas compliance, RMP support, conflict analysis mapping; FY 1986, oil field development field plan.

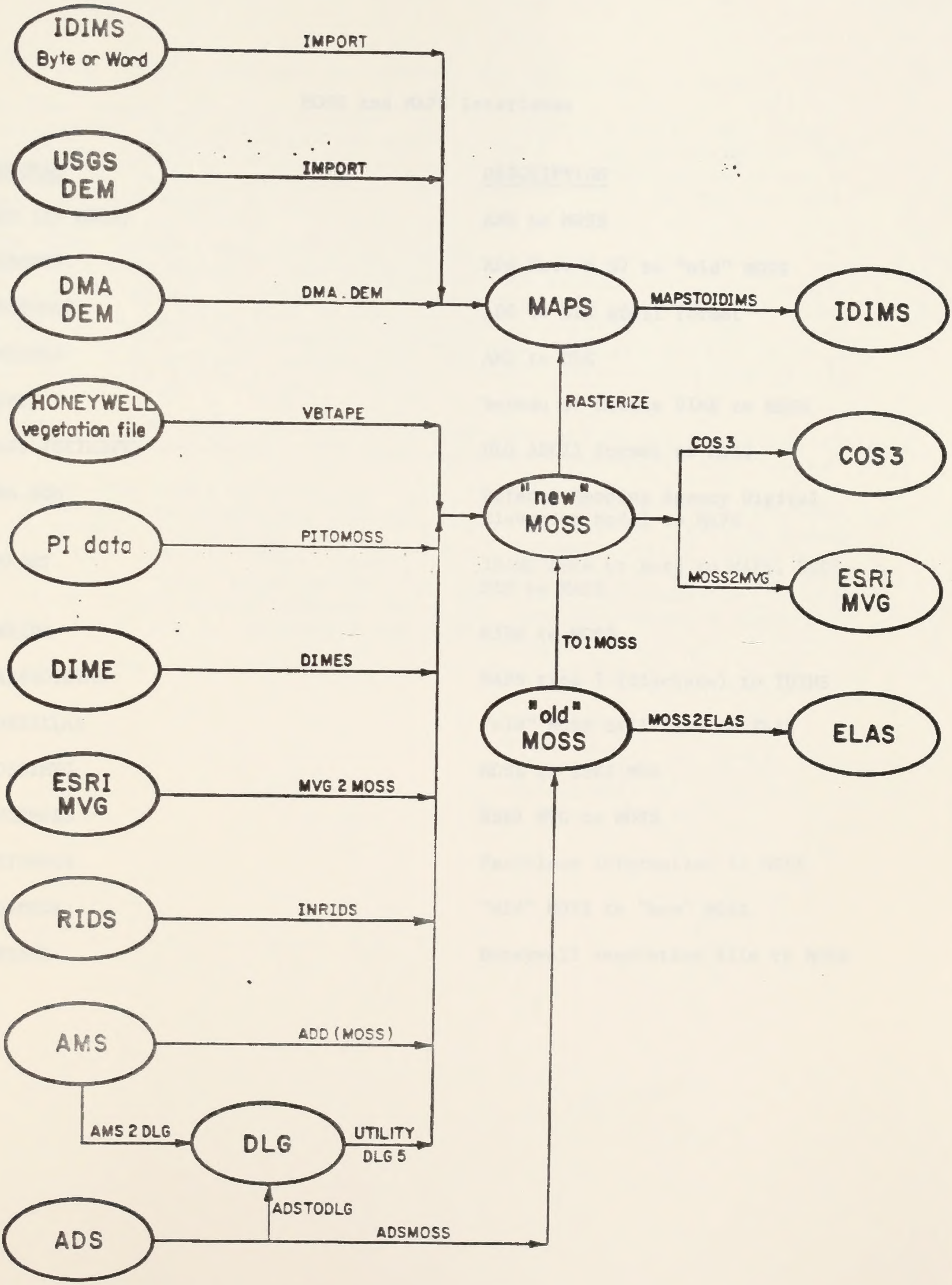
Powder River Basin Coal project in conjunction with Montana.

Green River Coal project in conjunction with Colorado.

Washakie R.A. - RMP support, includes range activity planning.

Cody R.A. - FY 1986, activity planning, range, oil and gas, wildlife, and RMP support.

MOSS and MAPS System Interfaces



MOSS and MAPS Interfaces

PROGRAM	DESCRIPTION
ADD (in MOSS)	AMS to MOSS
ADSMOSS	ADS Rev. 6.37 to "old" MOSS
ADSTODLG	ADS to DLG ASCII format
AMS2DLG	AMS to DLG
DIMES	Bureau of Census DIME to MOSS
DLG5 (UTILITY)	DLG ASCII format to MOSS
DMA.DEM	Defence Mapping Agency Digital Elevation Model to MAPS
IMPORT	IDIMS Byte or Word to MAPS, USGS DEM to MAPS
INRIDS	RIDS to MOSS
MAPSTOIDIMS	MAPS type 7 (discrete) to IDIMS
MOSS2ELAS	"old" MOSS cell file to ELAS
MOSS2MVG	MOSS to ESRI MVG
MVG2MOSS	ESRI MVG to MOSS
PITOMOSS	Petroleum Information to MOSS
TO1MOSS	"old" MOSS to "new" MOSS
VBTAPE	Honeywell vegetation file to MOSS

EXERCISE THREE - RECLASSIFY, OVERLAY AND DISTANCE IN MOSS

On his desk, an Area Manager has a proposed road improvement project in the Boxelder allotment on Wolf Ridge quadrangle. You have been asked to identify the following information in order to assist in impact assessment. At your disposal is the BLM GIS, and the Wolf Ridge data.

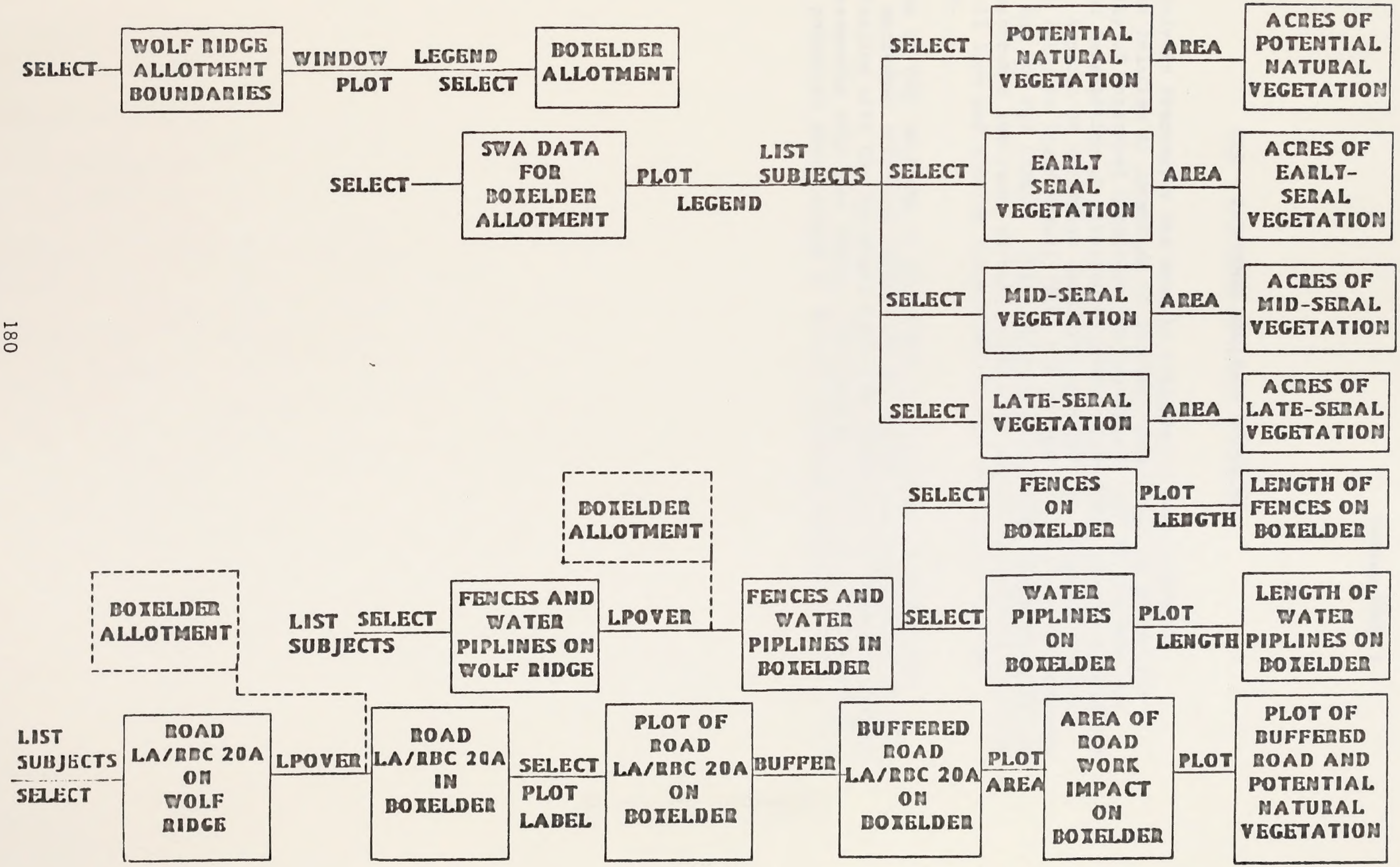
How many acres of potential natural vegetation are in the Boxelder allotment? How many acres of early seral, mid-seral, and late seral vegetation communities are in the Boxelder allotment? [HINT: the SWAWOLFRG map contains the SWA (soil write-up areas) for Boxelder allotment. Subject search strings are: PO = potential natural, EO = early seral, MO = mid seral, and LO = late seral.]

Prepare a map showing labelled fencelines and water pipelines in the Boxelder allotment. How many miles of fencelines are there?

The proposed road improvement will impact a 130 foot (0.0246 mile) wide swath through the Boxelder allotment. Create a map showing the construction area, i.e. a buffer zone of .0246 mile around the road. [The road is labelled LA/RBC20A on map TRNWOLFRG]. How many acres of Boxelder allotment will be affected by the construction? Will the road improvement activity affect any areas of potential natural vegetation?

Commands	Maps
LIST	ALBWOLFRG
SELECT	SWAWOLFRG
WINDOW	TRNWOLFRG
PLOT	PLFWOLFRG
SHADE	
LEGEND	
OVERLAY	
AREA	
LPOVER	
LENGTH	
BUFFER	

MODEL 3 - RECLASSIFY, OVERLAY AND DISTANCE IN MOSS



GIS - WATERSHED ANALYSIS EXERCISE

Watershed Analysis Procedures are used to evaluate current watershed conditions in relation to potential or desired conditions, to assess the susceptibility of watershed conditions to impairment, and to evaluate the resiliancy or feasibility of altering watershed conditions through management activities. Aspects of watershed condition analysis are described in BLM Draft Manual 7210, in Idaho Manual 7210, and in papers (attached) by Gebhardt (1985), and Van Der Puy (1986). While there are no prescribed procedures for conducting watershed analyses, certain aspects of watershed analysis relating to upland soil loss and erosion susceptibility are well suited for GIS applications.

The objective of this exercise is to conduct a simplified, hypothetical analysis of watershed soil-loss conditions and erosion susceptibility using a GIS in combination with the Universal Soil Loss Equation - a commonly applied method for assessing soil-loss rates. The purpose is to stimulate your own ideas about potential applications of GIS in watershed analysis.

Problem

The watershed component of an AMP is being developed. A vegetation conversion in the Sagebrush type is being contemplated. John Ho, the District Soil Scientist, has been asked to identify priority areas, from an erosion perspective, for such a conversion and to quantify what that activity might mean in terms of reduced soil-loss. Also, a pipeline is planned to pass through the allotment from north to south, and the DM wishes to identify areas which may be susceptible to severe erosion and require special restoration efforts.

John is familiar with the allotment and knows that from an erosion susceptibility standpoint, soils with erodibility (K) values greater than 0.32 on slopes greater than 10% - and especially those on slopes greater than 20% are highly susceptible to erosion when vegetation cover is reduced or eliminated. The soil 91 in SLSWOLFRG soil has a K value of 0.36. On the Boxelder allotment, the 91 soil supports a good cover of grass, but is easily invaded by brush when heavily grazed.

Tasks

I. John first wishes to identify areas where erosion susceptibility is high, and areas where it is moderate. He defines high erosion susceptibility as areas on 91 soils with slopes greater than 20%, and moderate erosion susceptibility as areas on 91 soils with slopes between 10-20%.

1. Create a map of 91 soils.
2. Create a high erosion susceptibility map.
3. Create a moderate erosion susceptibility map.

II. John believes that converting sagebrush to grass on high erosion susceptibility areas will benefit watershed condition. He wishes to identify areas of both high and moderate erosion susceptibility which are presently in the brush cover type.

1. Create a map showing where sagebrush occurs on high erosion susceptibility areas (search string = 523SG).
2. Create a map showing where sagebrush occurs on moderate erosion susceptibility areas.
3. Find out how many acres are in sagebrush on each of the two erosion susceptibility classes.

III. John now wishes to quantify existing erosion rates, and total soil loss amounts for each of the sagebrush areas identified in II above. He also wants to estimate what erosion rates and total erosion amounts would be under a grass cover situation. To do this he uses the USLE, given the following information:

$A = RKLSCP$

where R = rainfall factor (for $P_{2-6} = 2.0$ in)

$K = 0.36$

$L = 60$ ft. (from field inspection)

S = average of slope class

C = from table (attached) (or, assume "brush C" is 0.12 and "grass C" is 0.04)

A = soil loss rate, tons/acre/year

For total soil loss, he multiplies the rate for each map class by the total map area.

1. Would a vegetation conversion on the high or moderate "susceptibility" area result in the greatest reduction of total soil loss? Where would the vegetation treatment be most cost-effective from a soil-loss standpoint?

2. Compute salt load differences for a vegetation conversion on the high erosion susceptibility area, assuming soils average 1% salts by weight.

IV. Discussion Exercise:

Two alternative pipeline routes are given. The pipline requires removing all cover for 100 feet on either side of the pipeline. How many acres of high erosion susceptibility areas are impacted by alternative 1? Alternative 2?

V. If time permits, jot down some ideas as to how you might use a GIS in your soil-water program. If time doesn't permit, maybe you could discuss it at the tavern or motel hot tub.

C Values for Pasture, Range, and Idle Land

Factor **C** for a specific combination of cover conditions on these types of land may be obtained from table 10 (57). The cover characteristics that must be appraised before consulting this table are defined in the table and its footnotes. Cropstage periods and EI monthly distribution data are generally not necessary where perennial vegetation has become established and there is no mechanical disturbance of the soil.

Available soil loss data from undisturbed land were not sufficient to derive table 10 by direct comparison of measured soil loss rates, as was done for development of table 5. However, analyses of the assembled erosion data showed that the research information on values of **C** can be extended to completely different situations by combining subfactors that evaluate three separate and distinct, but interrelated, zones of influence: (a) vegetative cover in direct contact with the soil surface, (b) canopy cover, and (c) residual and tillage effects.

Subfactors for various percentages of surface cover by mulch are given by the upper curve of

TABLE 10.—*Factor* **C** *for permanent pasture, range, and idle land*[1]

Vegetative canopy		Cover that contacts the soil surface						
Type and height[2]	Percent cover[3]	Type[4]	Percent ground cover: 0	20	40	60	80	95+
No appreciable canopy		G	0.45	0.20	0.10	0.042	0.013	0.003
		W	.45	.24	.15	.091	.043	.011
Tall weeds or short brush with average drop fall height of 20 in	25	G	.36	.17	.09	.038	.013	.003
		W	.36	.20	.13	.083	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.076	.039	.011
	75	G	.17	.10	.06	.032	.011	.003
		W	.17	.12	.09	.068	.038	.011
Appreciable brush or bushes, with average drop fall height of 6½ ft	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.087	.042	.011
	50	G	.34	.16	.08	.038	.012	.003
		W	.34	.19	.13	.082	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.078	.040	.011
Trees, but no appreciable low brush. Average drop fall height of 13 ft	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.089	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.087	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.084	.041	.011

[1] The listed C values assume that the vegetation and mulch are randomly distributed over the entire area.

[2] Canopy height is measured as the average fall height of water drops falling from the canopy to the ground. Canopy effect is inversely proportional to drop fall height and is negligible if fall height exceeds 33 ft.

[3] Portion of total-area surface that would be hidden from view by canopy in a vertical projection (a bird's-eye view).

[4] G: cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 in deep.

W: cover at surface is mostly broadleaf herbaceous plants (as weeds with little lateral-root network near the surface) or undecayed residues or both.

TABLE 11.—*Factor C for undisturbed forest land*[1]

Percent of area covered by canopy of trees and undergrowth	Percent of area covered by duff at least 2 in deep	Factor C[2]
100-75	100-90	.0001-.001
70-45	85-75	.002-.004
40-20	70-40	.003-.009

[1] Where effective litter cover is less than 40 percent or canopy cover is less than 20 percent, use table 6. Also use table 6 where woodlands are being grazed, harvested, or burned.

[2] The ranges in listed C values are caused by the ranges in the specified forest litter and canopy covers and by variations in effective canopy heights.

figure 6. Subfactors for various heights and densities of canopy cover are given in figure 5. The subfactor for residual effects of permanent pasture, range, idle land, or grazed or harvested woodland has been estimated to vary from 0.45 to 0.10 (57). Major influences on this subfactor are plant roots, organic matter buildup in the topsoil, reduced soil compaction, and surface stabilization after long periods without soil disturbance. The **C** values given in table 10 were derived by combining subfactors for specified combinations of type, height, and density of canopy cover; type and density of cover at the soil surface; and probable residual effects of longtime existence of the specified cover on the land. They are compatible with the rather scarce existing soil loss data from undisturbed land areas.

C Values for Woodland

Three categories of woodland are considered separately: (1) undisturbed forest land; (2) woodland that is grazed, burned, or selectively harvested; and (3) forest lands which have had site preparation treatments for re-establishment after harvest.

In undisturbed forests, infiltration rates and organic matter content of the soil are high, and much or all of the surface is usually covered by a layer of compacted decaying forest duff or litter several inches thick. Such layers of duff shield the soil from the erosive forces of runoff and of drop impact and are extremely effective against soil erosion. Where cover by trees and litter is incomplete, the spots with little or no litter cover are partially protected by undergrowth canopy. Factor **C** for undisturbed forest land may be obtained from table 11. These estimated **C** values are supported by the quite limited existing data and also by the subfactor-evaluation procedure discussed in the preceding subsection.

Woodland that is grazed or burned, or has been recently harvested, does not merit the extremely low **C** values of table 11. For these conditions, **C** is obtained from table 10. However, the buildup of organic matter in the topsoil under permanent woodland conditions is an added factor that should be accounted for by a reduction in the **C** value read from table 10. An earlier publication (57) recommended a factor of 0.7 for this purpose.

Site preparation treatments for re-establishing trees on harvested forest land usually alter the erosion factors substantially. Canopy effect is initially greatly reduced or lost entirely, and its restoration is gradual. Some of the forest litter is incorporated in the soil, and it may be entirely removed from portions of the area. A surface roughness factor is introduced. Windrowed debris, if across slope, may function as terraces by reducing effective slope length and inducing deposition above and in the windrows. The amount of residual effect retained depends on the amount and depth of surface scalping. Some of the changes are analogous to cropland situations. Some of the relationships available from tables 5 and 10 can be used to evaluate **C** for these conditions, but neither table is directly applicable.

Table 12 presents **C** values computed for Southern Pine Forests that have had site preparation treatments after harvesting. This table was jointly developed (in 1977) by representatives of SEA, SCS, and Forest Service, using factor relationships from tables 5, 10, and 11 as basic guides. Its application on forest lands in other climatic regions may require some modifications of factor values. Research designed to refine and improve tables 10, 11, and 12 is underway.

Tree plantings on converted cropland should, in the initial years, be evaluated similarly to cropland because the forest residual effect which underlies tables 10 to 12 will not be applicable. The subfactor for residual effects may be estimated by selecting from lines 1 to 16 of table 5 the line that most nearly describes the condition of the converted cropland and assuming a residual subfactor equal to the seedbed-period value given in that line. If the cropland has most recently been in

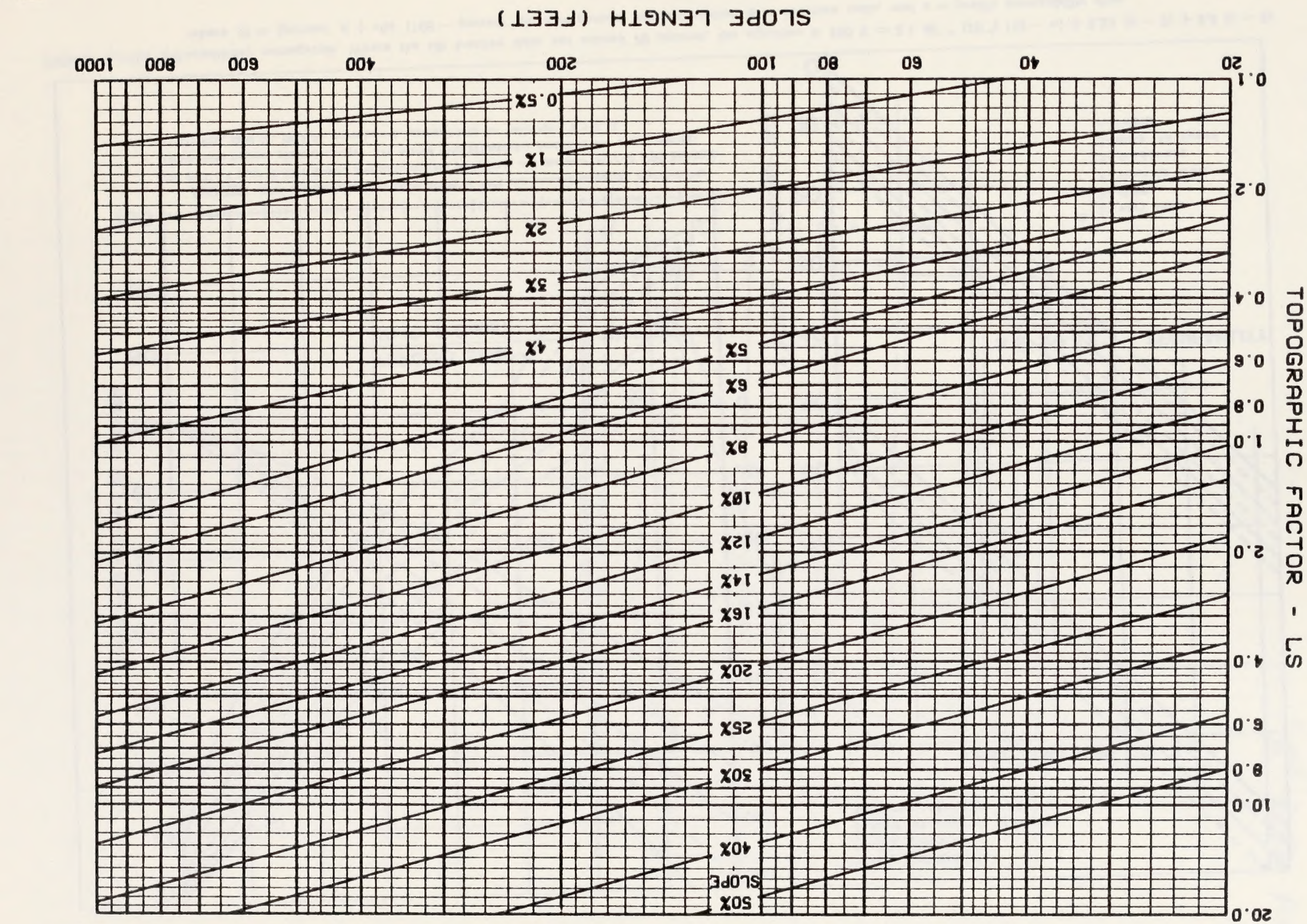


FIGURE 4.—Slope-effect chart (topographic factor, LS). $LS = (\lambda/72.6)^m\ (65.41\ \sin^2\theta + 4.56\ \sin\theta + 0.065)$ where λ = slope length in feet; θ = angle of slope; and m = 0.2 for gradients < 1 percent, 0.3 for 1 to 3 percent slopes, 0.4 for 3.5 to 4.5 percent slopes, and 0.5 for slopes of 5 percent or steeper.

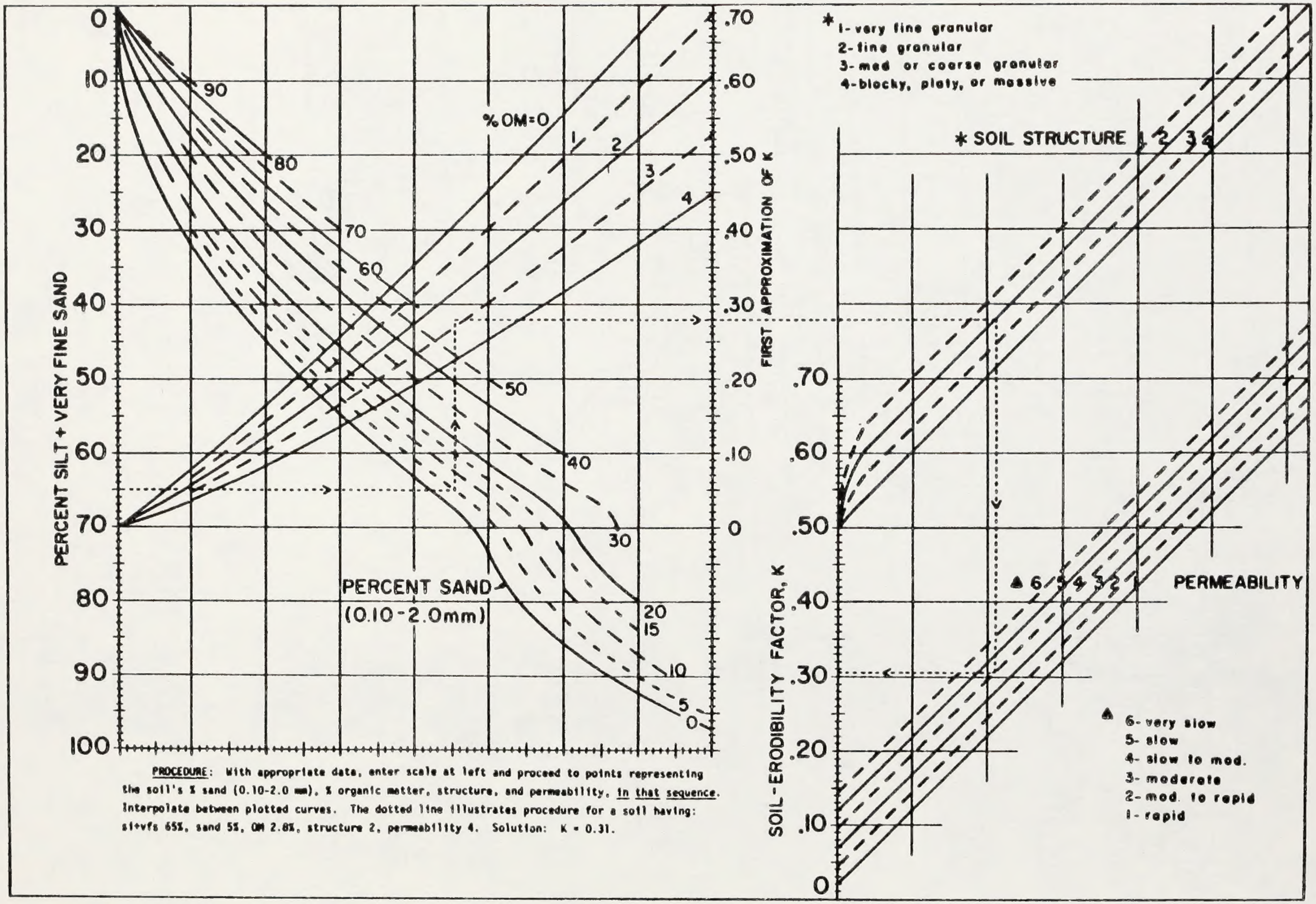


FIGURE 3.—The soil-erodibility nomograph. Where the silt fraction does not exceed 70 percent, the equation is $100\ K = 2.1\ M^{1.14}\ (10^{-4})\ (12 - a) + 3.25\ (b - 2) + 2.5\ (c - 3)$ where $M =$ (percent si + vfs) (100 — percent c), $a =$ percent organic matter, $b =$ structure code, and $c =$ profile permeability class.

USLE
"R" factor from P_{2-6}

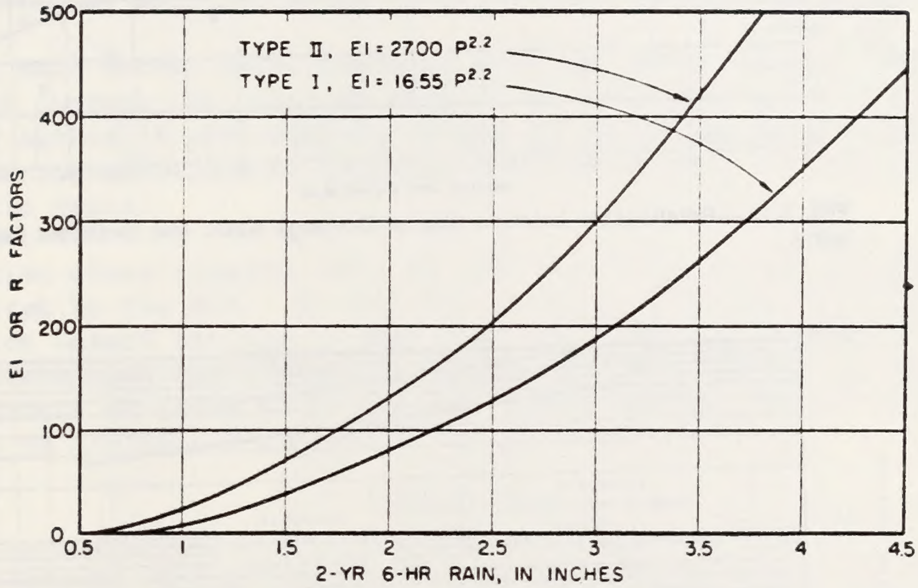


Fig. 6-13. Relation between annual average erosion index (EI on vertical axis) and 2-yr, 6-hr rainfall depth, rainfall types from (Ateshian 1974) p = precipitation.

Sediment Delivery Ratio

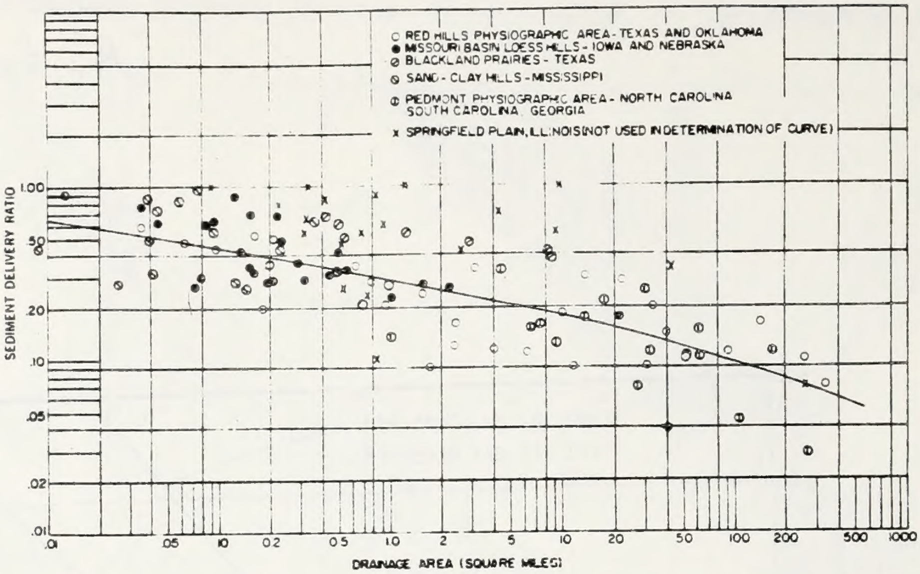


FIG. 4.13.—Relationship between Size of Drainage Basin and Sediment Delivery Ratio

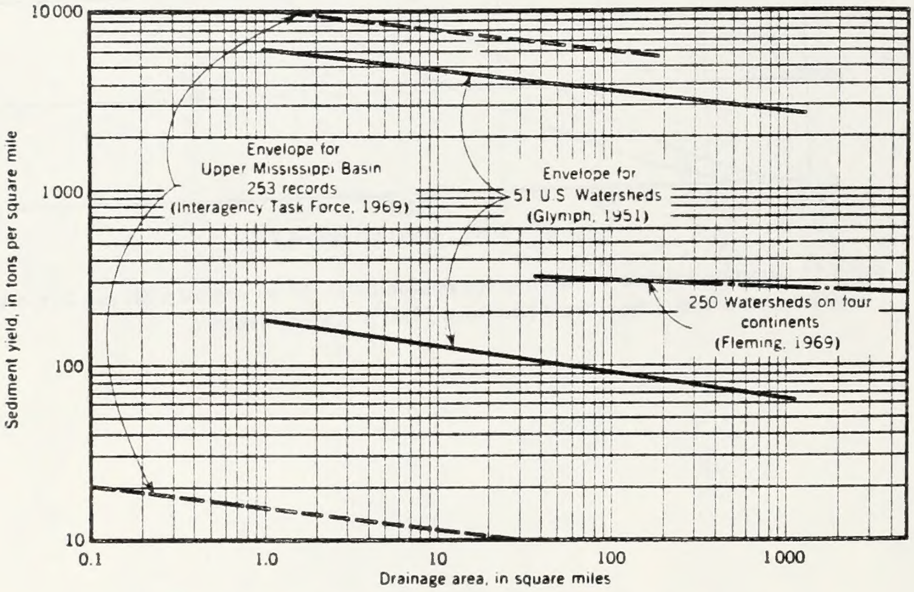


FIG. 4.14.—Effect of Watershed Size on Sediment Yield

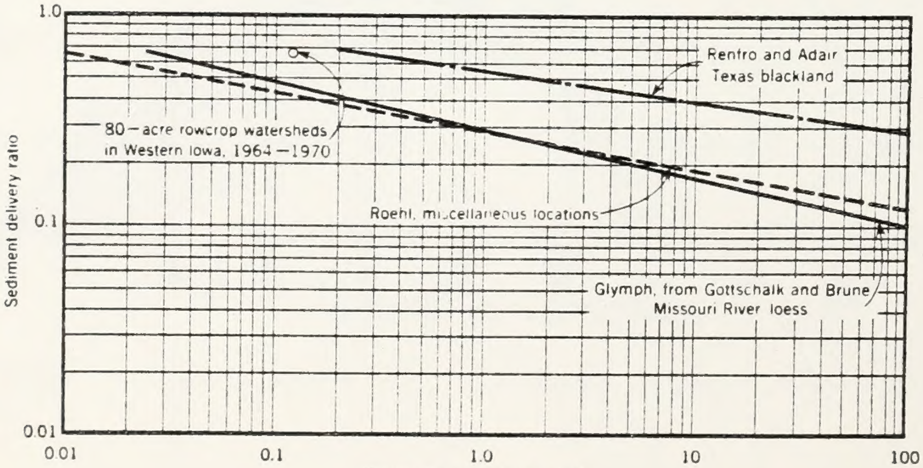


FIG. 4.15.—Effect of Watershed Size on Sediment Delivery Ratio

IN: Proceedings of the Fourth Federal Interagency Sedimentation Conference, Las Vegas, 1986

RATING EROSION SUSCEPTIBILITY

By Mark E. Van Der Puy, District Hydrologist, Phoenix District Office, U.S.D.I. Bureau of Land Management.

ABSTRACT

An Erosion Susceptibility Rating System was devised to provide land managers with an adequate and meaningful evaluation of current erosion conditions and erosion hazards as related to specific large scale resource management programs.

Using existing soil survey data, combined wind and water erosion hazard ratings can be developed to compare the relative effects of management alternatives on soil erosion. This method is particularly useful in comparing alternative routes for linear-type disturbances such as transmission line routes, gas pipelines and off-road vehicle races.

Erosion condition classification data is also available on 154 million acres of land administered by the BLM. By coupling erosion condition classifications with combined erosion hazard ratings, a dual component Erosion Susceptibility Rating System can be developed for particular watersheds. The effect of large scale resource management programs on particular watersheds can then be assessed. This method focuses on current or potential problem areas.

INTRODUCTION

Watershed specialists employed by the Bureau of Land Management or other agencies responsible for managing vast acreages of public land are often called upon to assess the environmental impact of large scale resource management programs. Typically, these specialists estimate changes in sediment yield or erosion as a function of changes in vegetative cover using the Pacific Southwest Inter-agency Committee (PSIAC) method or universal soil loss equation (USLE).

The problem with these approaches is that they rely on speculative cover values and involve time consuming calculations to generate numbers that mean very little to decision makers.

A practical method of assessing the impacts of proposed developments or management plans on the watershed system, specifically those impacts involving soil erosion and stream sedimentation, is yet to be established for large scale management areas as encountered in the BLM. This is evident in the variety of assessment formats used in the environmental assessment process.

APPROACHES TO IMPACT ASSESSMENT

Specialists assigned with the task of evaluating watershed impacts typically rely on the Universal Soil Loss Equation (Wischmeier and Smith, 1965) or the Pacific Southwest Inter-agency Committee (PSIAC, 1968) methods to quantify estimates of on-site erosion or sediment yield. An assessment of technical problems with these methodologies is beyond the scope of this paper; it is sufficient to note that there is considerable controversy regarding the applicability or adequacy of these methods for predicting erosion losses and sediment yield from arid and semi-arid rangelands.

When watershed specialists are requested to make their predictions, they inevitably focus on the parameter most likely to change: cover. Assuming existing cover

values are available, the specialist must first speculate on changes in cover resulting from the proposed action; from this professional judgement lengthy calculations are then made for numerous watersheds or grazing allotments. The final product is units, either tons/acre/year or acre-feet/square mile of soil loss or sediment yield. The decision-making manager must ultimately be convinced of the significance of these units. He must weigh these units against grazing numbers or systems, miles of rights-of-way approved, or number of off-road vehicle (ORV) races authorized.

Krupin (1980) addressed the problem in a multi-parametric approach which discounted the value of calculating estimates of soil loss or sediment yield. He used a rather lengthy process which considered geomorphic, soil, vegetation, lithographic and related parameters in developing a susceptability rating for a unit of land. Managers could then base decisions on miles or square miles of land disturbed in areas with different susceptability ratings.

This direction in watershed impact assessment challenged the basic precept that quantification provides the best answers. The complexity and time requirement of the system used by Krupin, however, proves to be a disadvantage for very large land management areas.

EROSION HAZARD RATING

With the advent of Order 3 and 4 soil surveys on BLM lands, specialists have been given a valuable tool in assessing watershed impacts. Among the products of these soil surveys are mapped delineations of soil associations. Map Unit Descriptions (MUD's) describe each of these associations in a uniform format. Included in each MUD are evaluations of the wind and water erosion hazards of each major soil group found within the mapping unit.

Figures 1 and 2 are excerpts from the Nevada SCS Soils (Form 5) Guide USDA-SCS (1983). These demonstrate how the soil erodibility factor (K) is developed. The K factor is multiplied by slope (S) to determine the water erosion hazard as follows:

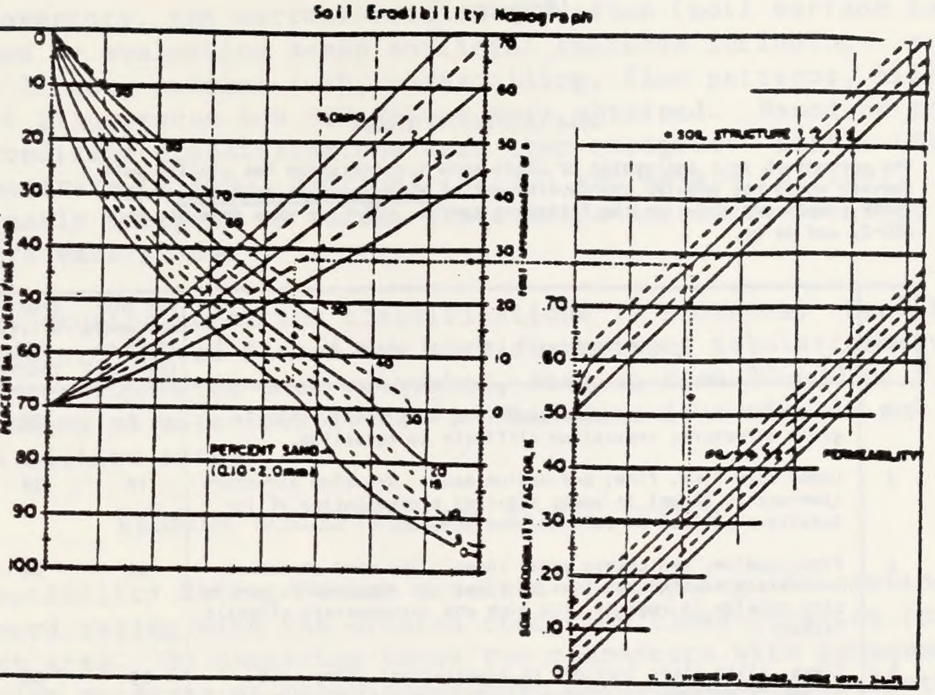
S X K	Water Erosion Hazard
4	Slight
4-8	Moderate
8	High

Evaluation of the wind erosion hazard is similar. The predominant soil textural class is used as illustrated in Figure 3 to determine the Wind Erodibility Group (WEG). A similar rating scheme as the water erosion hazard can be used as follows:

WEG	Wind Erosion Hazard
5-8	Slight
3,4	Moderate
1,2	High

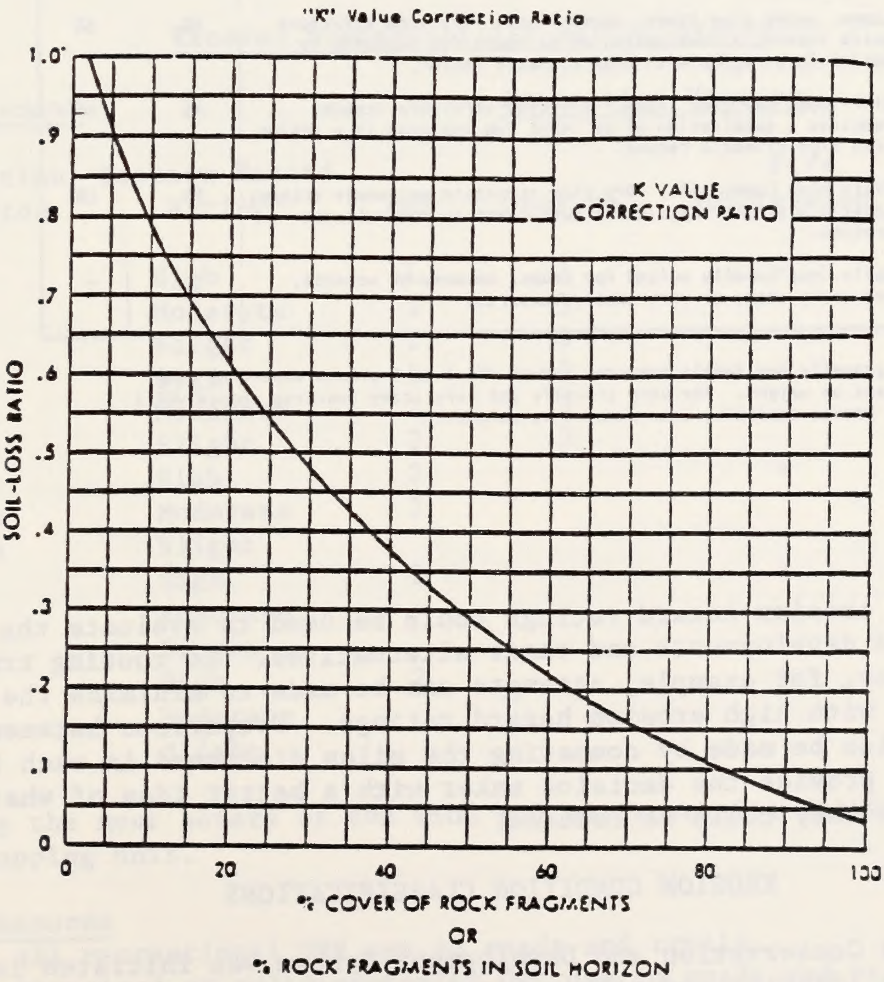
Based on this soil survey information, combined erosion hazard ratings can be made for each MUD. A MUD with the dominant family having respective water and wind erosion hazards of high and moderate, for example, would have combined hazard rating of H/M. If there were two equally dominant taxonomic groups in the MUD, the range of hazard rating would be listed on tabulations or overlays as M-H/S-M.

Figure 1



Reprinted from the Journal of Soil and Water Conservation
September-October 1971, Volume 26, Number 5

Figure 2



INSTUCTION FOR USE

1. Average percent rock fragments for the horizon.
2. Go on vertical line to curve.
3. Go horizontally to SOIL-LOSS RATIO.
4. Multiply K from nomograph by S-LR to get corrected K.

Figure 3

Wind Erodibility Groups

The percent of soil aggregates or clods show a correlation for similar soil texture which has enabled the development of Wind Erodibility Groups (WEG). These groups are shown on the following table. WEG-1 is more erodible than WEG-2, and so on.

WEG	Predominant soil textural class 1/	Dry soil aggregate >0.84 mm (percent)	Erodibility "I" T/A/Yr.
1	Very fine, fine and medium sand (and dune sand). Single grain structure; vegetation difficult to establish.	3	220
2	Loamy very fine, fine, and medium sand. Dry clod structure (percent >0.84 mm) is weak; requires a combination of intensive practices to control wind erosion.	10	134
3	Fine, medium, and coarse sandy loams. Dry clod structure moderately stable; requires at least two measures to control wind erosion in regions with high and intermediate climatic factor.	25	86
4	Clays, silty clays (subject to granulation). Dry clod structure extremely variable due to contraction and swelling by freezing and thawing and wetting and drying; need a combination of at least two measures to control erosion.	25	86
4L	Clay and silty clay high in lime which is conducive to floculation and granulation.		
5	Loams, sandy clay loams, sandy clays. Dry clod structure quite stable; a combination of at least two measures is needed in a region with high climatic factor.	40	56
6	Silt loams and clay loams. Dry clod structure stable; requires a combination of at least two measures in a region with high climatic factor.	45	48
7	Silty clay loams, silt. Dry clod structure extremely stable; usually a single practice is sufficient to control wind erosion.	50	38
8	Soils (not usually suited for crops) because of wetness, extremely stony or very cobbly textures.	-	-

1/ For gravelly and cobbly textures reduce WEG 1 to 2 groups depending upon percent by weight. For very gravelly and very stony textures reduce WEG 2 to 3 groups depending upon percent by weight.

An overlay showing erosion hazard ratings could be used to evaluate the impacts of proposed developments and their alternatives. In routing transmission lines or ORV courses, for example, attempts can be made to minimize the miles disturbed in areas with high erosion hazard ratings. Comparison between alternatives can also be made by comparing the miles disturbed in each hazard group. This would provide the decision maker with a better idea of what the impacts are and how they could be reduced.

EROSION CONDITION CLASSIFICATIONS

The BLM's Watershed Conservation and Development System was initiated in 1970 as a six-phase system to identify and attain watershed objectives on specific geographic areas. Phase I consisted of field inventory, as outlined in BLM Manual 7322 and by Clark (1980).

As part of this inventory, the current erosion condition (soil surface factor, or SSF) was determined by evaluating seven surficial features including: soil movement, surface litter, surface rock, pedestalling, flow patterns, hills and gullies. Figure 4 illustrates how SSF values were obtained. Based on these SSF values, erosion condition classifications were then assigned: stable (SSF 0-20), slight (21-40), moderate (41-60), critical (61-80) and severe (81-100). Management objectives are greatly designed to reduce disturbance and increase cover in critical and severe watersheds.

Available data for erosion condition classifications is enormous. Each BLM District in the western United States has both summarizing tabulations and overlays depicting erosion conditions on each watershed, ranging from 20-400 mi.^{2}, with transects representing no more than 10 mi.^{2}. This data is available on approximately 154 million acres.

EROSION SUSCEPTIBILITY RATING SYSTEM

The Erosion Susceptibility Rating System consists of coupling the combined wind and water erosion hazard rating with the erosion condition classification for each watershed transect area. By comparing these two components with proposed uses of the land, protective measures or other management needs can be promulgated. Table 1 illustrates how the Erosion Susceptibility Rating System might be used.

Table 1

Erosion Susceptibility Rating System

Component		Protective Measure		
Erosion Condition Classification	Erosion Hazard Rating[a]	ORV	Grazing	Fire Suppression
Severe	High	1	3	4
Severe	Moderate	1	3	
Severe	Slight	1	3	
Critical	High	1	3	4
Critical	Moderate	2	3	
Critical	Slight	2	3	
Moderate	High	2		4
Moderate	Moderate	2		
Moderate	Slight			
Slight	High	2		4
Slight	Moderate			
Slight	Slight			
Stable	High	2		4
Stable	Moderate			
Stable	Slight			

[a]Representing the most severe of the wind and water erosion ratings for a particular mapping unit.

Protective Measures
1. Restrict all recreational ORV use to roads and trails.
2. Restrict organized or multi-vehicular ORV use to roads and trails.
3. Change management of grazing animals in such a way that vegetative and ground litter cover increase incrementally by 25%.
4. Consider these areas as high priority fire suppression zones.

Figure 4

Form 7310-12
(March 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

DETERMINATION OF EROSION CONDITION CLASS
SOIL SURFACE FACTORS (SSF)

By: RLK | Date: Sept 10, 1968
Location: 27-04-OC3 WA
Transect T 1609121
Treatment affecting the SSF: Present ○; W/o mgt change □; Land use mgt change X; With added treatment α

SOIL MOVEMENT*	No visual evidence of movement 0 1 2 3	Some movement of soil particles 4 5	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height 6 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 14
SURFACE LITTER*	Accumulating in place 0 1 2 3	May show slight movement 4 5 6	Moderate movement is apparent, deposited against obstacles 7 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining (use care on low productive sites) 12 13 14
SURFACE ROCK*	If present, the distribution of fragments show no movement caused by wind or water 0 1 2	If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water 3 4 5	If present, fragments have a poorly developed distribution pattern caused by wind or water 6 7 8	If present, surface rock or fragments exhibit some movement and accumulation of smaller fragments behind obstacles 9 10 11	If present, surface rock or fragments are dissected by rills and gullies or are already washed away 12 13 14
PEDESTALLING*	No visual evidence of pedestalling 0 1 2 3	Slight pedestalling, in flow patterns 4 5 6	Small rock and plant pedestals occurring in flow patterns 7 8 9	Rocks and plants on pedestals generally evident, plant roots to 10" exposed 10 11	Most rocks and plants pedestalled and roots exposed 12 13 14
FLOW PATTERNS*	No visual evidence of flow patterns 0 1 2 3	Deposition of particles may be in evidence 4 5 6	Well defined, small, and few with intermittent deposits 7 8 9	Flow patterns contain silt and sand deposits and alluvial fans 10 11 12	Flow patterns are numerous and readily noticeable. May have large barren fan deposits 13 14 15
RILLS	No visual evidence of rills 0 1 2 3	Some rills in evidence at infrequent intervals over 10' 4 5 6	Rills [illegible] to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills 6" to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 12	May be present at 3" to 6" deep at intervals less than 5' 13 14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 2 3	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 6	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present 7 8 9	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 12	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15

SITUATION	TOTAL	
		Present SSF, ○ = 19+21 = 40; W/o mgt change □ = 13+29 = 42;
		Land use mgt change, X = 6+23 = 29; With Added Treatment, α = 13+9 = 22;

Erosion Condition Classes: Stable 0–20, Slight 21–[illegible] [illegible]

EXAMPLES

ITEM	EXAMPLE ONE			EXAMPLE TWO**			EXAMPLE THREE***		
	POTENTIALLY PRESENT	IDENTIFIED FACTORS	POSSIBLE FACTOR	POTENTIALLY PRESENT	IDENTIFIED FACTORS	POSSIBLE FACTOR	POTENTIALLY PRESENT	IDENTIFIED FACTORS	POSSIBLE FACTOR
Soil Movement	Yes	8	14	Yes	8	14	Yes	8	14
Surface Litter	Yes	9	14	Yes	9	14	Yes	9	14
Surface Rock	Yes	7	14	No	-	--	No	-	--
Pedestalling	Yes	10	14	Yes	10	14	Yes	10	14
Rills	Yes	8	14	Yes	8	14	No	-	--
Flow Patterns	Yes	10	15	Yes	10	15	Yes	10	15
Gullies	Yes	6	15	No	-	--	No	-	--
TOTAL		58	100		45	71		37	57
Total SSF		$\frac{58}{100} \times 100 = 58$			$\frac{45}{71} \times 100 = 63$			$\frac{37}{57} \times 100 = 65$	

GENERAL INSTRUCTIONS

District prepares one (1) copy and files in district with particular study under consideration.

Do not include items in computations which are not potentially present.

Identify numerical factor that most nearly describes the conditions observed by circling the factor given for each logical item.

*Wind and water are considered eroding agents when evaluating item

** A soil with no rocks in its profile and no probability of gullying

*** A pumice soil area where no water erosion occurs

SPECIFIC INSTRUCTIONS

Total all factors at bottom of page. Divide total identified factors by total possible factors for items considered and multiply by 100 in order to compute the SSF.

Situation – Describe situations being evaluated such as present, geologic, with mechanical treatment in effect for 10 years, under a 5 pasture livestock management system for last 8 years, etc.

Total – Total computed SSF.

One advantage of this system is that it can be developed prior to proposals for major activities on public lands, such as interstate transmission line corridors, multi-million acre grazing system, ORV courses hundreds of miles in length, etc. The specialists can evaluate each proposed action and develop protective measures specific to that action.

Another advantage is that most of the data is already available throughout the BLM, involving some 154 acres of public land. Erosion condition classifications have been available since the early 1970's. Order 4 soil surveys cover most of the areas administered by the BLM; more detailed Order 3 surveys are now underway.

Possibly the biggest advantage of this system is that it does not rely on speculation to generate numbers which are meaningless to decision makers. Rather, it focuses on identifying specific measures required to protect or improve current or potential problem areas.

Summary

Current approaches to assessing watershed impacts usually involve the USLE, PSIAC, or other methods which provide quantitative estimates of on-site erosion or sediment yield. In addition to the inherent weaknesses of these methods, the final product is usually a number which is meaningless to the decision maker.

An alternative to these approaches utilizes existing soil survey information. Soil Erosion Hazard Ratings can be used to route activities away from soils poorly suited to withstand surface disturbance. Specialists working on lands administered by the BLM also have available to them Erosion Condition Classification data. By coupling these existing pieces of data, specific measures can be identified to protect or enhance both current and potential problem areas.

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Erosion, Productivity and Rangeland Watershed Planning

Karl A. Gebhardt, P.E., Member ASCE[1]

Abstract

A quantifiable approach to watershed management planning is presented using the concepts of existing condition, potential condition, tolerance, vulnerability, and responsiveness. Two models, the Erosion and Productivity Impact Calculator (EPIC) and the Simulation of Production and Utilization of Rangelands (SPUR), are considered to provide an analysis tool for the watershed management planning approach.

Background

The Bureau of Land Management is responsible for the management of over 160 million acres of rangeland in the western United States. The principal uses of these rangelands are the grazing of wildlife and domestic livestock, mineral exploration and extraction, and public purposes such as recreation and waste disposal. Domestic livestock grazing is the largest single use of the public lands. Livestock grazing was generally unmanaged from its onset in the mid 1800's until the passage of the Taylor Grazing Act in 1935. In testimony before the Senate Committee on Public Lands and Surveys, Congressman Taylor spoke:

> "I might mention that when I was District Attorney of Northwestern Colorado, I prosecuted eight different murder cases at one term of court, the greatest number of them being the outcome of the fights over the use of the range, mostly between cattle and sheep graziers... I call your attention to the fact that we are rapidly permitting the creation of small Sahara Deserts in every one of these States today. We have such conditions in southern parts of Colorado at this time, where there is nothing left but sand which drifts back and forth, hither and yon with every breeze."

Those remarks were typical of the conditions of western rangelands in the mid-1930's. With the passage of the Taylor Grazing Act came the formation of the Grazing Service to enforce the Act. Unfortunately, many who were involved with the administration of the Act underestimated

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the scope of the rangeland problem. In many cases, the hard decisions necessary to reverse the deterioration of the range were not made (2).

In 1946, Congress combined the Grazing Service and the General Land Office into what is now the Bureau of Land Management (BLM). In the early 1950's the Bureau set a 10-year goal to bring grazing into balance with the capacity of the Federal range to produce forage (2). Progress toward that goal was made; however, in 1972 there still was 32 percent of public range in poor condition.

Five years after the passage of the National Environmental Policy Act (NEPA) in 1969, the Natural Resources Defense Council (NRDC) brought suit against the Secretary of Interior for noncompliance with NEPA. The suit resulted in the BLM having to prepare 141 environmental impact statements (EIS) on their grazing management programs.

In 1976, Congress realized the need for a change in the policies regulating the public lands and passed the Federal Land Policy and Management Act (FLPMA). This Act made some minor changes in the Taylor Grazing Act and reversed the old policy of disposal of public lands. FLPMA also stated the importance of water resources and maintenance of long-term productivity.

The last major public land legislation was the Public Rangelands Improvement Act of 1978 (PRIA) that would fund $ 360 million for rangeland improvements over a 20 year period. However, to date no monies have been appropriated through the act.

In order to help reach some of the goals of FLPMA and PRIA the BLM has initiated a selective management concept using three categories: (M) maintenance, which includes highly productive range generally in satisfactory condition; (I) intensive management, which includes range in poor to fair condition with a high potential for improvement; and, (C) custodial, which includes range in stable condition with little potential for improvement.

Watershed Management

Proper watershed management has been a primary concern since the BLM was formed and continues to be a major justification for intensive BLM planning and range improvement activities. Watershed management in the 1960's consisted of many mechanical "treatments" for erosion problems. Keeping the soil in-place and maintaining a productive site (vegetative) was the major objectives of these projects. The level of engineering and analysis that went into these early projects was determined by the training and experience of the on-the-ground employees. As a result, early BLM erosion control projects ranged from highly successful to disastrous.

In the 1970's with the advent of NEPA the BLM began to get more technical with determining the impacts of land use on erosion. In almost every environmental impact statement, a section on soil and water could be found. Typically, these documents were summaries of impact analyses using a soil loss equation such as described by Musgrave (3) and the Universal Soil Loss Equation (9). Lacking site specific and verified data, analyses were general, which is expected when dealing with management areas of several hundred thousand hectares. A major concern expressed by land managers in these documents was the effect of erosion on soil productivity. Yet many EIS's inadequately described the factors in the erosion equations and most failed to quantify productivity.

Currently, the BLM is still involved with grazing EIS's and other environmental analyses dealing with land-use plans and projects. There is still a concern about erosion and soil productivity, but now more powerful tools are becoming available to assess the relationships between land use, productivity, and erosion for use by the on-the-ground professionals.

There are several reasons why complex assessment tools have not been widely used by the field professional. These include: lack of data, degree of complexity, and lack of validated or universally accepted relationships. Fortunately, technology is rapidly taking care of the latter two problems through computerization and advances in our understanding of erosion processes. Lack of data will always be a problem to those who seek better, more definitive answers. However, some needed data may be unattainable due to lack of funds.

The purpose of this paper is to present an approach to watershed management using a planning system and general application of two state-of-the-art rangeland watershed models, particularly with reference to erosion and soil productivity.

The Planning System

The planning system is assumed to be issue driven--it relies on some important areas of concern to be addressed before planning action begins. The system produces a plan written specifically for the manager who must use it to make land-use decisions. The planning process considers existing conditions as well as potential conditions and the probability of them occurring.

Within the watershed management concept of the planning system, the four major areas of concern are: (1) water quality, (2) water quantity and its timing, (3) erosion, and (4) sedimentation. All watershed management analyses are described in terms of these four concerns. For a particular area, the beneficial uses determine which concerns will be analyzed. For example, an area containing a stream would have concerns of water quality, water quantity (instream flows, flooding, etc.), erosion, and sedimentation, while another area may have fewer concerns.

Each concern for a particular area can be described in terms of five descriptors. They are: (1) existing conditions, (2) potential conditions (both favorable and unfavorable), (3) tolerances, (4) vulnerability, and (5) responsiveness.

To illustrate how descriptors are used, erosion will be assumed to be the major concern on a currently productive, loamy site.

The existing condition using best available procedures is found to be 0.5 kg soil loss/ha. The manager is not too concerned with precise soil loss values, but is more concerned with the long-term ability of the site to remain productive. This is the ultimate assessment of existing condition.

The potential worst condition is found to produce a maximum soil loss of 5.5 kg/ha/yr (with removal of vegetation cover), and a best condition to provide 0.2 kg/ha/yr (with maximum potential vegetation cover). This range provides the specialist with a clue as to effects of possible uses and the relative status of the existing condition.

Tolerance is defined as the point at which soil loss becomes unacceptable to management. For our example tolerance is that point where long-term soil productivity is decreased. In this case, assume it is 1.0 kg/ha/yr. We now know that our existing condition is acceptable.

Vulnerability is defined as the likelihood of the existing erosion condition to become worse within a set time. Since our example site has moderately high erodibility and the climate has a high potential for producing runoff, the site is considered highly vulnerable.

Responsiveness, on the other hand, is the ability of the site to recover, provided the stress factors causing the undesirable conditions are removed. Our example site is very productive and has a deep soil profile. With adequate rest, the site could reach a minimum soil loss condition in as little as 5 years provided the site has not been physically altered.

As the example shows, there are many factors to consider in determining current condition, setting tolerances, and analyzing potential conditions, vulnerability and responsiveness. Proper application of the planning system requires a great deal of knowledge about the site and its likely response to environmental changes. Several years ago a detailed approach to complex watershed planning was almost unthinkable, but now it is possible with the availability of physical process models and high-speed computers.

The Models

We will now examine the possibilities of applying two rangeland models in answering basic rangeland management questions dealing with planning. The two models are the EPIC (Erosion Productivity Impact Calculator) and SPUR (Simulation of Production and Utilization on Rangelands), currently under development by the U.S.D.A. Agricultural Research Service.

The EPIC model was developed by Williams (8) to determine the relationship between soil erosion and productivity for aiding the assessment of the soil resources in the United States as required by the Soil and Water Resources Conservation Act (RCA, PL 95-192). The model was developed for cropland application, although it has been applied to rangelands with favorable results (1). Springer et al. (6) have developed illustrative examples of the use of EPIC on rangelands. The conclusions indicate that EPIC may answer many rangeland management questions. Problems dealing with long-term annual forage removal and erosion may be EPIC's primary use (1,6).

The EPIC model (8) is designed for the analysis of areas small enough in size that the soils and management can be considered homogeneous. Soil profiles can be represented by up to 10 layers, with a top layer set and maintained at 10 mm (for soil loss estimating purposes). Major components within the model include: hydrology, weather, erosion, nutrients, plant growth, soil temperature, tillage, and economics. The model simulates surface runoff volume, peak discharge, evapotranspiration, percolation, lateral subsurface flow, drainage, irrigation, and snowmelt within the hydrology component. Weather information in the forms of daily precipitation, air temperature, and solar radiation are required input and can be generated within the model. Water erosion is calculated using a modification to the Universal Soil Loss Equation (4,9). Wind erosion can also be predicted using a modification of the Manhattan Kansas wind erosion model (10). Nitrogen and phosphorous are cycled within the model. Loss of these nutrients in surface runoff and sediment transport is considered. Plant growth is based on accumulated heating units and energy interception by the photosynthetically active portion of the canopy, and regulated by the available water, temperature, and nutrients. Tillage is used in the model for nutrient mixing. No options are currently available to consider other physical or biological soil mixing processes. The EPIC model produces some economic analyses and has options to consider certain operational controls such as drainage, irrigation, fertilization, liming, and pest control.

The Simulation of Production and Utilization of Rangelands (SPUR) model is being developed by the U. S. Department of Agriculture (7) as a physically based, rangeland ecosystem model to aid both management and research. It is designed to be applicable on a wide variety of rangeland types with a minimum amount of calibration.

The SPUR model has a basin-scale version for large, hydrologic applications, and a field-scale version used to simulate rangeland ecosystems. This paper will limit the discussion to the field-scale version. The major components within the model are climate, hydrology, plant growth, domestic animal growth, and economics. The model can simulate the plant and animal interaction on up to nine sites within the field. Each site can have up to seven plant species or functional groups. Utilization of plant species by livestock can be regulated by assigning preference vectors for plant species, landform types, and physical limitations within each site. The plant growth component simulates plant biomass and nitrogen in a soil-plant system by tracking the carbon and nitrogen flows in the system. The model is designed to run on a daily time step and requires daily input variables for precipitation, temperature, solar radiation, and wind run.

Both models have inherent limitations to solving some of the rangeland management questions. The EPIC model has not been fully adapted to rangelands and its major limitation is its inability to simulate rangeland communities (something more than a monoculture). EPIC uses only tillage to mix soil nutrients and does not consider factors such as soil movement provided by arthropods or other organisms. The ability of EPIC to evaluate grazing systems is questionable since there is no technique available for harvesting on a daily, weekly or monthly basis. A modification of the USLE (4) is used as the primary erosion equation, and therefore EPIC is constrained by some of the knowledge limitations of the USLE related to rangeland cover and management.

The field-scale version of the SPUR model has no site specific erosion-handling routine, and does not consider loss of nutrients via runoff or erosion. Its current code does not allow for automated changes is grazing dates from year to year.

Applying the Models

Both the EPIC and SPUR models can be applied in solving watershed management questions dealing with erosion and soil productivity. Both models can be used to ask "what if" questions using either historical or

generated input data. The EPIC model could be applied to look at the soil/nutrient loss from a site and its effect on long-term production of a range site. The results from the EPIC model would provide a direct answer in terms of soil loss as compared to SPUR results which would provide soil loss response indirectly through vegetation changes.

Use of models in determining information for the five planning descriptors (existing condition, potential conditions, tolerance, vulnerability, and responsiveness) in terms of erosion will be discussed.

Existing conditions can be determined by field measurement of soil loss; however, this is not practical over a large area because of time and cost. Existing conditions for erosion can be estimated using site specific climate, soil, slope, and cover data related to soil erosion such as described in the Universal Soil Loss Equation (9). Since it is obvious that such a determination has a great deal of variability dependent on the method of measurement and field observer, the estimation of existing condition might vary considerably from one observer to another.

The EPIC model has the ability to generate erosion values based on historical climatological and vegetation records. Whether the absolute value of estimated erosion is correct or incorrect is immaterial to some of the comparative applications, as will be shown later.

Potential conditions are useful in establishing the likely range of erosion rates under conditions of maximum vegetative cover and minimum vegetative cover. While the SPUR model does not directly translate production values into percent vegetative cover, some assumptions of production to cover relationships can be made for each species. Once such a relationship is established, the output from the SPUR model, which includes above ground live biomass, litter, and seeds, can be used to generate a range of ground cover data for various environmental stresses. Since the SPUR model can use simulated or historical climatic data and various grazing pressures, a set of ground cover and climate data could be used in the EPIC model to determine the range of erosion rates expected on the site at various probabilities/stress levels.

Tolerance is perhaps the most important descriptor within the planning system. When considering erosion and soil productivity, the tolerance value is the amount of soil erosion that results in a long-term loss in productivity. This could be determined by using an historical set of climate data where unacceptable loss in productivity occurred or a set of critical climate data that would represent some probable percent of rainfall energies likely to occur. The EPIC model would be used with this set of data and the amount of vegetation would be adjusted until the productivity was acceptable. The long-term soil loss, as calculated by EPIC, would then become a tolerance value. There are other factors involved in setting a tolerance such as the managers willingness to accept production loss, the ability to mitigate losses, and the length of planning period (i.e. 10 years, 20 years, 50 years). The approach to determine a tolerance must be tailored to the site and the type of use that would be occurring.

Vulnerability on rangelands is best examined by applying various environmental stresses on the site and measuring the response via changes in plant production or community structure. The SPUR model this type of examination, provided the environmental stresses that would be expected to occur are carefully selected. In addition, it is also important to establish a fixed set of environmental stresses that could be applied over all of the sites in a planning area. This would result in a comparative ranking of sites for planning categorization (such as M, I, C, discussed above). The SPUR analysis combined with soil loss values from EPIC would provide a reasonable comparative analysis, independent of absolute soil loss values.

Responsiveness is determined by an approach similar to vulnerability by examining the rate of improvement in a site based on some set of fixed environmental conditions. The SPUR model would again be used to simulate vegetation production and community structure. The results of such an analysis would be used to rank management sites in order of success for recovery. This ranking could aid in cost/benefit analysis and influence final decisions of which sites would be best for rehabilitation funding.

Conclusion

A planning system requiring a quantifiable analysis of existing and future conditions could be met through two state-of-the-art rangeland models. However, both models are in the development stage and there are drawbacks inherent in the equations used to calculate such things as erosion and plant growth. The EPIC model would deal primarily with long-term site responses to erosion and gross vegetation response, while the SPUR model would be used to analyze site specific plant and community response to environmental stress. The advantages of the models use include: the ability to recreate environmental conditions; the ability to simulate conditions; the ability to develop probabilities for risk analysis; consistency in data handling and analysis; and, the ability to rapidly conduct analysis.

Some of the drawbacks associated with the models are being addressed in projects such as the Rangeland Universal Soil Loss Equation effort (5), being conducted cooperatively by the USDA Agricultural Research Service and the Bureau of Land Management, and many other rangeland ecosystem studies. In the examination of the EPIC and SPUR models, it is obvious to the authors that combining some of the functions of the EPIC model into the SPUR model would simplify such analysis approaches as described in this paper. The level of complexity of watershed management problems can be analyzed using a quantitative planning approach and predictive modeling. In addition, the manager can have a much more definitive set of management tools than ever before possible.

APPENDIX I.--REFERENCES

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2. Herndon, Paul, "History of Grazing on the Public Lands," The Taylor Grazing Act, 50 Years of Progress, U. S. Department of Interior, Bureau of Land Management, Boise, Idaho, 1984, pp. 1-6.
3. Musgrave, G. W., "The Quantitative Evaluation of Factors in Water Erosion--A First Approximation," Journal, Soil and Water Conservation, Vol. 2, 1947, pp. 133-138.
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6. Springer, E. P. et al., "A Methodology to Assess Range Management Practices Using the EPIC Model," U. S. Department of Agriculture, Agricultural Research Service, Boise, Idaho, In preparation.
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8. Williams, J. R., Jones, C. A., and Dyke, P. T., "A Modeling Approach to Determining the Relationship Between Erosion and Soil Productivity," Transactions, American Society of Agricultural Engineers, Vol. 27, No. 1, 1984, pp. 129-144.
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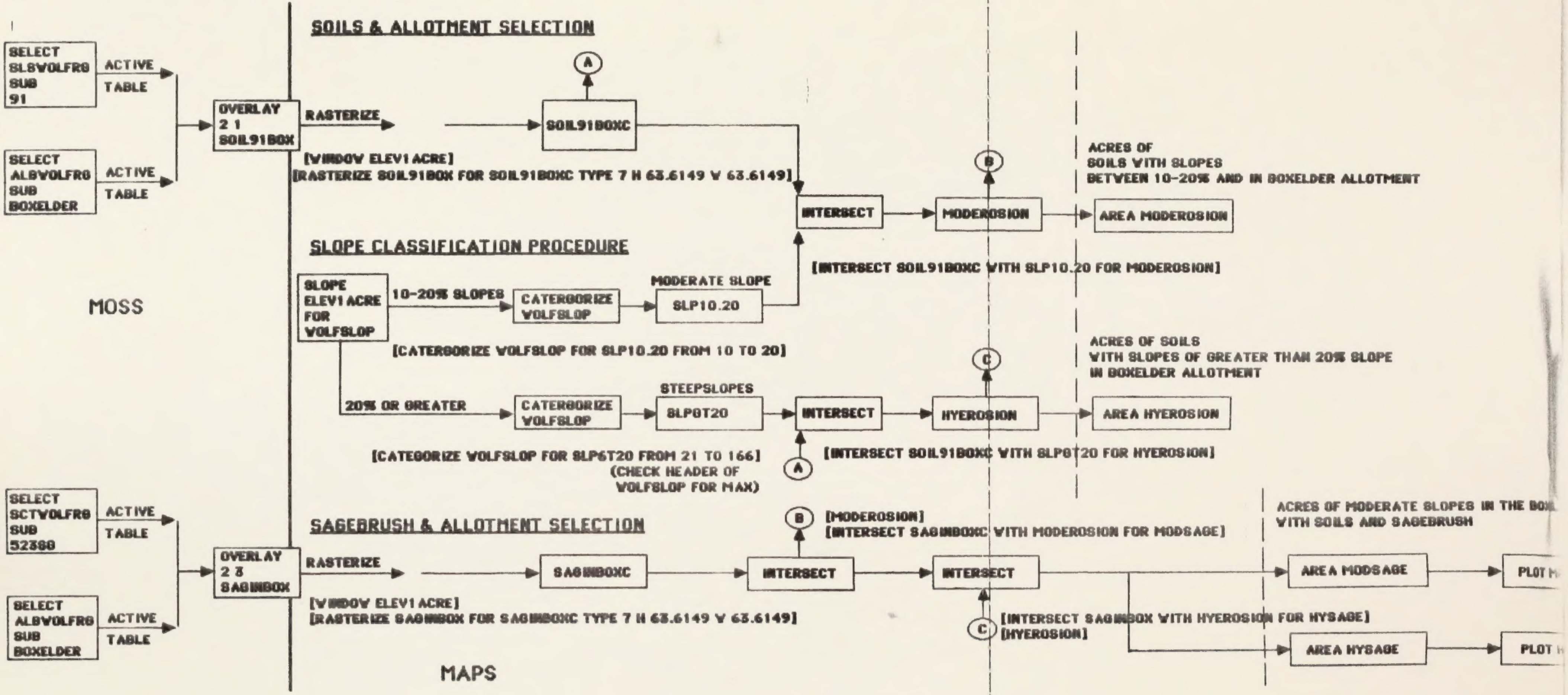
10. Woodruff, N. P. and Siddoway, F. H., "A Wind Erosion Equation," Proceedings, Soil Science Society of America, Vol. 29, No. 5, 1965, pp. 602-608.

WATERSHED EXERCISE



COMPUTER MODELS

Course 7000.1
Instructors: Gebhardt
Jackson

USING PERSONAL COMPUTERS

(With Lab Sessions in Design Hydrology and Computer Modelling)

Objectives

(1) To learn basics operation and terminology for IBM compatible personal computers.

(2) To be able to use Microsoft Disk Operating System (MS-DOS).

(3) To be able to create and edit files.

(4) To learn the basic theories of probability and risk analysis in hydrologic design and apply those theories to the solution of practical problems.

(5) To learn the basic theory and operation of several common analytical procedures in hydrology and apply those procedures to the solution of practical problems using a computer.

(6) To learn what computer models are and what they do.

(7) To be able to run several computer models.

Topic Outline

I. INTRODUCTION TO COMPUTERS

A. What can they do for you?

B. What can't they do for you?

C. Frustrations and Satisfactions

II. PC BASICS

A. Hardware

B. Software

C. Disk Operating System

D. File Handling

III. GETTING TO KNOW THE PC

A. How to begin

B. Interactive programs

C. Manuals

D. Where to go for help

E. Learning to type

F. Using MS-DOS

G. File creation

H. Editing

IV. COMPUTER LAB: DESIGN HYDROLOGY

A. Introduction

1. Flow Frequency

2. Probability

3. Risk Analysis

B. Handout Problem in Risk Analysis

C. Flow Frequency: Log-Pearson III distributions

D. Computer Exercise: Log-Pearson III analysis

E. Rainfall-Runoff Modelling: SCS Methods; Synthetic Hydrographs

F. Computer Exercise: SCS Curve Number Model

G. Flood Routing Computer Exercise: Routing a runoff event through a small reservoir.

H. Introduction to Design Sedimentation

V. INTRODUCTION TO MODELLING

A. What do models do?

B. Types of models

C. Formulating a model

D. Flow Charts

E. Input/Output

F. Programming languages

G. Compilation

VI. COMPUTER LAB: RUNNING MODELS

ABBREVIATED RESUME

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Current responsibilities:

Liaison between Bureau of Land Management and Agricultural Research Service.

Saval Research Program, Research Hydrologist

Hazardous Materials Management Program Leader

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Education:

B.S. - Civil Engineering, University of Utah, 1974
M.S. - Environmental Engineering, Utah State University University, 1976

Affiliations:

American Society of Civil Engineers
Water Pollution Control Federation
American Water Works Association
Chi Epsilon
Tau Beta Pi
Registered Professional Engineer
Certified Professional Hydrologist (AIH)

Areas of Publication and Presentation:

Erosion and Sediment
Computer modeling
Land Use Planning
Groundwater modeling
Landfill design and evaluation
Riparian Hydrology
Hazardous Waste

GETTING STARTED WITH THE SOIL, WATER, AND AIR PERSONAL COMPUTER PROGRAMS

1. THE PERSONAL COMPUTER (PC) SHOULD BE TURNED OFF.
2. PLACE THE MS-DOS DISK IN DRIVE A AND TURN THE PC ON.
3. WHEN PROMPTED, ENTER THE DATE AND TIME.
4. AFTER THE A: PROMPT APPEARS, TYPE "B:". YOU SHOULD THEN SEE THE B: PROMPT.
5. AFTER THE B: PROMPT, TYPE "GO". THE MAIN MENU WILL APPEAR.
6. FROM THIS MAIN MENU, YOU CAN CHOOSE TO RUN THE HYDROLOGY OR STATISTICAL PROGRAMS. PLACE THE APPROPRIATE PROGRAM DISK IN DRIVE B.

OTHER INTERACTIVE WATER HYDROLOGY COMPUTER PROGRAMS

CURRENTLY AVAILABLE ON THE BLM HONEYWELL DPS-8 COMPUTER

PROGRAM: KAY (SCS Curve Number Runoff Model)

ACCESS: * BRN A403/KAY, R

DESCRIPTION: This program is a storm runoff model based on SCS Curve Number methods. The program calculates runoff volume and develops a synthetic hydrograph for a user-defined rainfall depth, duration, and distribution. Watershed input parameters include area, average land slope, channel length, and Curve Number. Single or multiple small watersheds may be analysed concurrently, although there are no provisions for channel routing (see "FLOOD" program for flood routing analyses).

PROGRAM: NEWYHD (SCS Curve Number Runoff Model)

ACCESS: *BRN A403/NEWHYD, R

DESCRIPTION: Same as the KAY program, but optionally "writes" a hydrograph output file that ROUTE "reads."

PROGRAM: ROUTE (Reservoir Routing)

ACCESS: *BRN A403/ROUTE, R

DESCRIPTION: This program routes a hydrograph output from NEWYHD through a detention reservoir with a weir type emergency spillway.

PROGRAM: CHANL and MCHANL (Channel Geometry)

ACCESS: *A403/CHANL or A403/MCHANL (metric version)

DESCRIPTION: These programs reduce and analyze stream channel cross-section survey data collected by either a rod and level survey or a sag tape survey. Data may be entered from the keyboard or a file. Cross sections are plotted on X-Y coordinates and discharge rating curves are developed using Manning's equation given a user-supplied value for Manning's "n." Output tables also include values for average flow velocity (for each discharge increment), cross-section area, wetted perimeter, and hydraulic radius.

PROGRAM: ERHYM (Forage production model)

ACCESS: *A403/ERHYM

DESCRIPTION: ERHYM is a range site scale model which provides daily simulation of soil water evaporation, transpiration, runoff, and soil water routing. Herbage yield is computed annually at peak standing crop. It can run either on a seasonal basis with new soil water boundary conditions at the beginning of each year's growing season, or continuously utilizing a simple snowmelt-temperature relationship to account for snowmelt infiltration and runoff, and overwinter recharge. The model requires one or two climate files and a parameter file which can be created interactively within the ERHYM program.

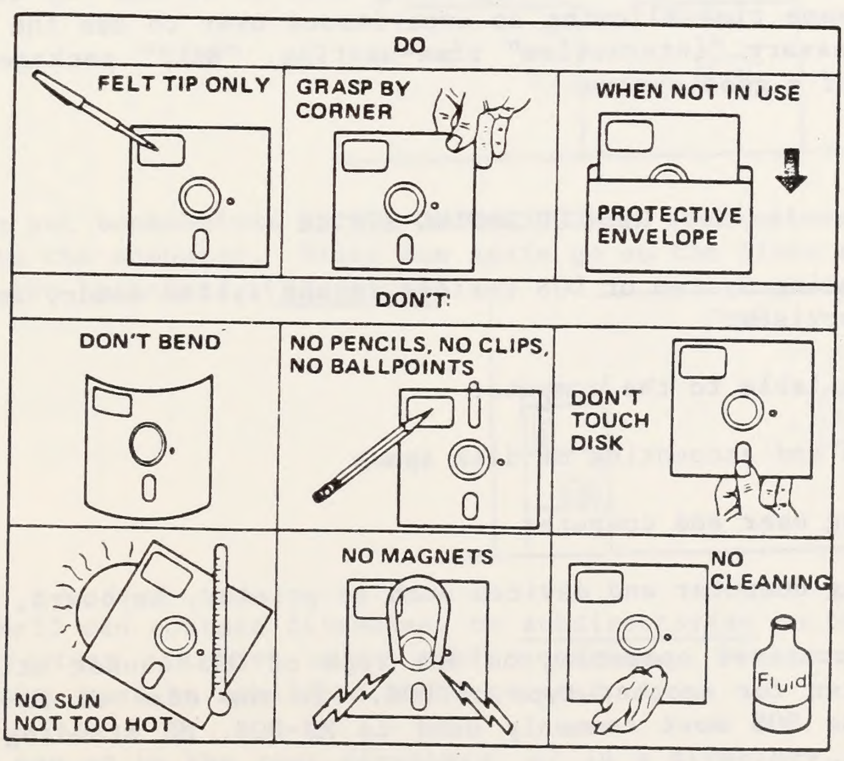
SOFTWARE

Software is contained on magnetic media and contains the "code" or instructions necessary to make the computer function. Typical software comes on "floppy" diskettes or cassette tape. Some software is contained on computer chips and is actually resident inside the computer. This is called "firmware".

Software is available to do many functions. Common classes of software are:

- Word processing and editing
- Data base management (ASPEN)
- Graphics
- Tutorial
- Statistics
- Programing
- Models
- Communications

Care and handling of software



NEVER REMOVE A FLOPPY DISKETTE FROM A DRIVE WHEN ITS RED LIGHT IS ON!!

MANUALS

Manuals are instructions to the user on what the software does, how it works, how to make it work, etc. It also contains a license for use.

The quality of a software package is largely judged by the quality of the manual and the ease of use of the software.

Manuals usually contain the following parts:

Introduction

Installation

Beginning sections

Application sections

Advanced sections

Appendices -- Troubleshooting, reference, technical stuff

Index

EASE OF USE

Ease of use of a particular software depends on the user.

Quality software should allow a beginning user to be led "by the hand" while at the same time allowing an experienced user to use the system without unnecessary "interactive" time-wasting. "HELP" packages are usually part of a good system.

DISK OPERATING SYSTEM

The Disk Operating System or DOS resides in the system memory and takes charge or supervises:

Memory available to the computer

Allocation and accounting of disk space

Interfacing user and computer

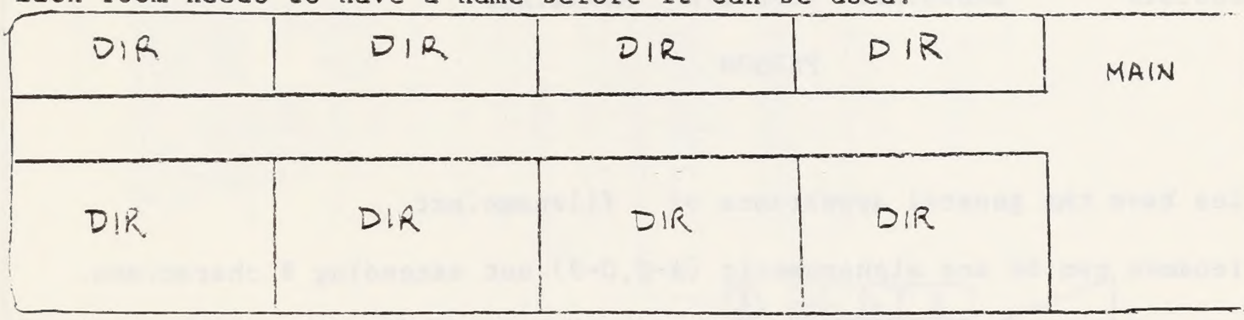
Interfacing computer and devices such as printer, keyboard, monitor

Generally, a computer operating on one type of DOS cannot utilize programs written for another type of DOS. In the case of IBM and compatibles the DOS most commonly used is MS-DOS, MS standing for Microsoft Corp.

FILE HANDLING

File handling within a computer is similar to document handing in an office or book handling in a library.

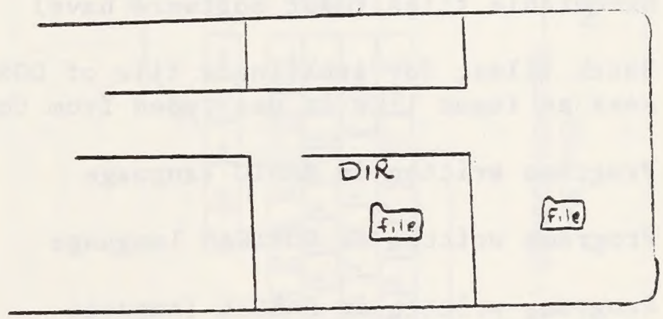
Let's pretend we have an office and in the office are halls and many rooms.
Each room needs to have a name before it can be used.



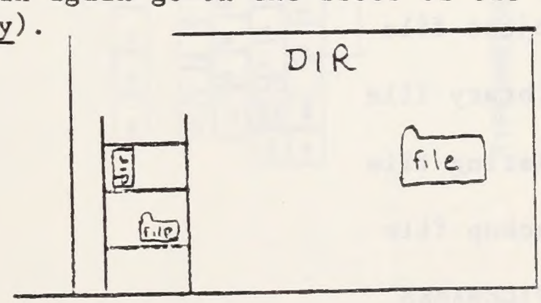
In the computer, the office is like our floppy disk.

Each room is like a root directory.

Now if we have a file and we want to put it somewhere, we can put it directly on the office floor or we can specify it to go in one of the rooms.



We can also put bookshelves in the rooms. These bookshelves is like a directory to the computer. Files can again go on the floor of the room, or now, on the bookshelf, (directory).



Each bookshelf can contain fileboxes, or subdirectories to the computer. Each subdirectory can have other subdirectories. Directories and subdirectories must be specified to be created.

Now a file can go in the root directory, or in a directory, or any of many subdirectories.

FILES

```
        >........................DISK..............................<

   DOS      START.BAT     WP              DATA        SOILS       WATER

COMMAND.COM       REPORTS    LETTERS    FLOW.DAT    SOILS5.BAS   SWRRB.EXE
IN.SYS                                  ASPEN.EXE   SOILS5.DAT   H2O.DAT
MSDOS.SYS        EROSN.RPT   USFS.LTR   MONIT.ASP

                             PERSON
```

Files have the general appearance of filename.ext

Filenames can be any alphanumeric (A-Z,0-9) not exceeding 8 characters.

The "ext" is the file extension and cannot exceed 3 characters.

Some extension have special meaning:

COM Command files, containing DOS commands

EXE Executable files (most software have)

BAT Batch files, for creating a file of DOS commands that the computer sees as input like it was typed from the keyboard.

BAS Programs written in BASIC language

FOR Programs written in FORTRAN language

PAS Programs written in PASCAL language

C Programs written in C language

OBJ Object file

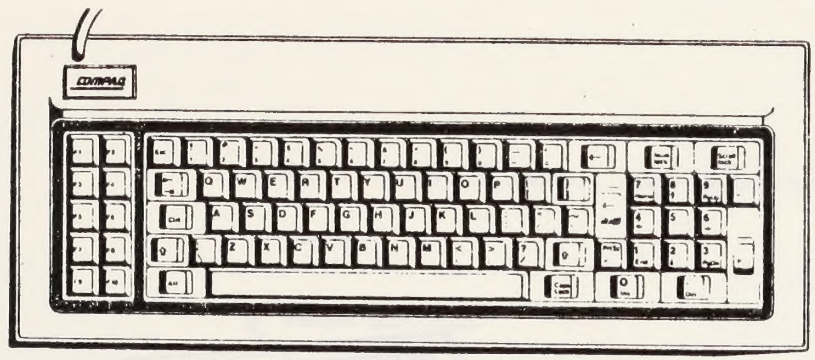
LIB Library file

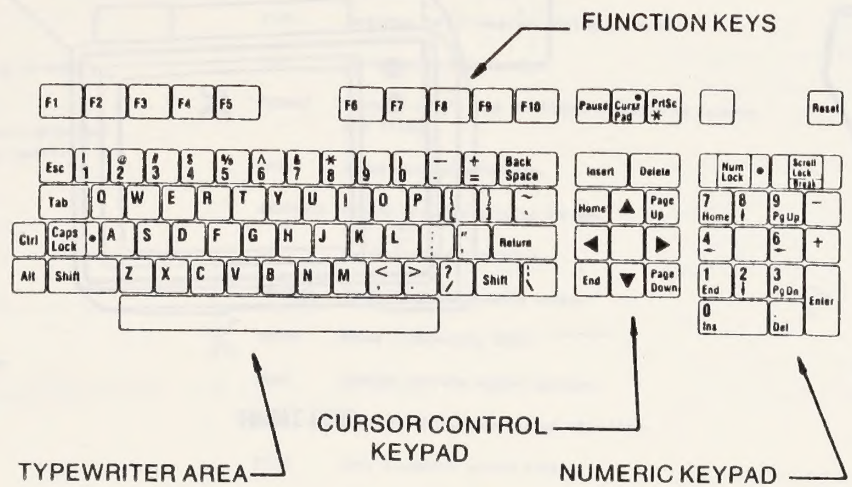
MAP Listing file

BAK Backup file

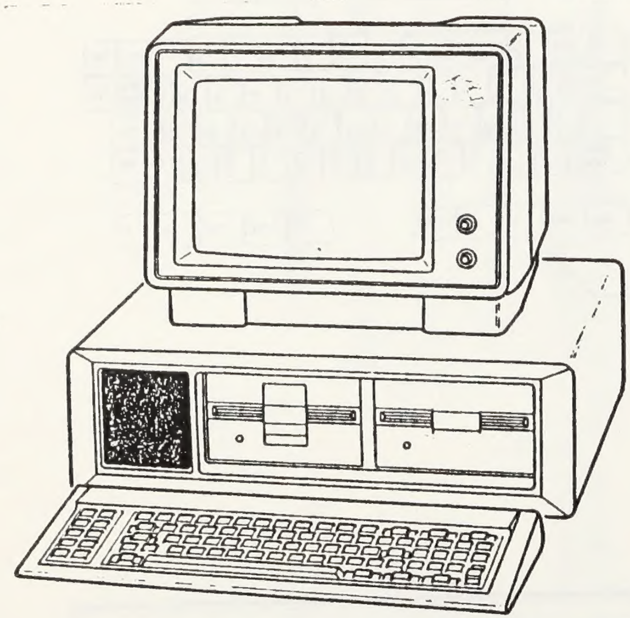
DEVICE FILENAMES

AUX referring input or output from or to an auxillary device
CON referred to either keyboard input or output
LST referred to line printer
NUL does not create a file, used where command require proper format




FUNCTION KEYS
CURSOR CONTROL KEYPAD
TYPEWRITER AREA
NUMERIC KEYPAD

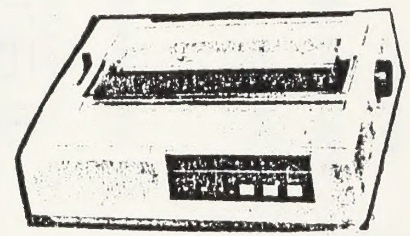
MONITOR



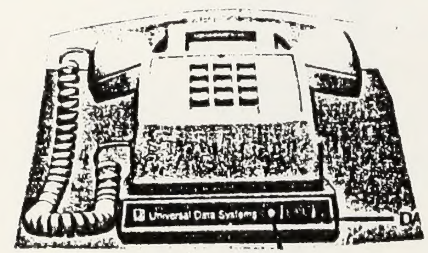
FLOPPY DRIVE

KEYBOARD

PRINTER



FIXED DRIVE (HARD DRIVE)



MODEM

SECTION 4

COMMANDS

INTRODUCTION

NOTE: Users of single-drive systems should refer to Appendix A for the additional procedures required when executing many of the following commands.

All of the commands described in this section are listed below (the letters enclosed in parenthesis at the end of the descriptions are the alternate name that can be entered for the command).

ASSIGN	Routes requests to a different drive.
BACKUP	Backs up hard disk files.
BREAK	Sets Ctrl-Break check.
X CHDIR	Changes directories; prints working directory (CD).
CHKDSK	Checks disk on designated or default drive and produces a disk and memory status report.
CLS	Clears screen.
X COPY	Copies file(s) specified.
CTTY	Change to an auxiliary console.
DATE	Displays and sets date.
X DIR	Lists requested directory entries.
DIRCOMP	Compares directories.
DISKCOMP	Compares two floppy diskettes.

COMMANDS

X DISKCOPY	Copies disks.
DISKTEST	Tests the accuracy of the read/write heads and data integrity.
ECHO	Turns batch file echo feature on/off.
X ERASE	Erases file(s) specified.
EXE2BIN	Converts .EXE files to .COM files.
EXIT	Exits command and returns to lower level.
FDISK	Prepares a hard disk for use.
FIND	Searches for a constant string of text.
FOR	Batch command extension.
X FORMAT	Formats a hard disk or floppy diskette to receive DOS files.
GOTO	Batch command extension.
GRAPHICS	Prints graphics display screen.
IF	Batch command extension.
MEMTEST	Tests installed memory chips.
X MKDIR	Makes a directory (MD).
MODE	Specify certain system options.
MORE	Displays output one screen at a time.
PATH	Sets a command search path.
PAUSE	Pauses for input in a batch file.

COMMANDS

PHDINIT	Erases and initializes the hard disk drive.
PRINT	Background print feature.
PROMPT	Designates command prompt.
RECOVER	Recovers a bad disk.
REM	Displays a comment in a batch file.
X REN	Renames first file as second file (RENAME).
RESTORE	Restores files that have been placed on diskette(s) (via the BACKUP command) back to the hard disk.
RMDIR	Removes a directory (RD).
SET	Sets one string value to another.
SHIFT	Increases number of replaceable parameters in batch process.
SORT	Sorts data alphabetically, forward or backward.
SYS	Transfers DOS system files from the default drive to the drive specified.
TIME	Displays and sets time.
TREE	Displays all directory paths on specified drive.
X TYPE	Displays contents of specified file.
VER	Displays DOS version number.
VERIFY	Verifies while writing to disk.
VOL	Displays volume identification number.

EDLIN FILENAME . EXT

INTERLINE COMMANDS

Interline commands perform editing functions on whole lines at a time. The Interline commands are summarized in Table

5-2 and are described in detail following the description of command parameters.

Table 5-2

EDLIN COMMANDS

COMMAND	PURPOSE
<LINE>	EDITS LINE NO.
A	APPENDS LINES
C	COPIES LINES
D	DELETES LINES
E	ENDS EDITING
I	INSERTS LINES
L	LISTS TEXT
M	MOVES LINES
P	PAGES TEXT
Q	QUITS EDITING
R	REPLACES LINES
S	SEARCHES TEXT
T	TRANSFERS TEXT
W	WRITES LINES

Parameters

Each Interline command accepts some optional parameters. The following list of parameters indicates their form. The effect of a parameter depends on the command it is used with.

Parameter	Definition
<line>	Indicates a line number that you type. Line numbers must be separated by a comma or a space from other line numbers, other options, and from the command.

Parameter		Definition
		<line> may be specified one of three ways:
	Number	Any number less than 65534. If a number larger than the largest existing line number is specified, then <line> means the line after the last line number.
	Period	If a period (.) is specified for <line>, it indicates the current line number. The current line is the last line edited, and is not necessarily the last line displayed. The current line is marked on your screen by an asterisk (*) between the line number and the first character.
	Pound	The pound sign (#) indicates the line after the last line number. If you specify # for <line>, this has the same effect as specifying a number larger than the last line number.
	Return	A carriage return entered without any of the <line> specifiers listed above directs EDLIN to use a default value appropriate to the command.
?		Directs EDLIN to ask you if the correct string has been found. The question mark is used only with the Replace and Search commands. Before continuing, EDLIN waits for either a "Y" or Return for a yes response, or any other key for a no response.
<string>		Represents text to be found, to be replaced, or to replace other text. The <string> option is used only with the Search and Replace commands. Each <string> must be ended by F6 or Return.

RB EXE RBEDIT.MSG

The two numbers inside the angle brackets indicate the position of the cursor in the file. The first number is the line number. The second number is the column number (1 through 80).

RBEDIT can create or modify a command file of up to 800 command lines, depending on available memory. The screen displays 23 lines at a time.

The RBEDIT key functions are shown in table 15-1.

Table 15-1 RBEDIT Key Functions

To browse through pages:*

[Home]	Display the first page of the text file
[End]	Display the last page of the text file that is shown by moving to the last line in the file
[PgUp]	Display the previous page by moving up 20 lines in the file and displaying 23 lines
[PgDn]	Display the next page by moving down 20 lines in the file and displaying 23 lines

To move the cursor in line units:

[↓]	Move down one line
[↑]	Move up one line
[Ctrl] [→]	Move to end of current line
[Ctrl] [←]	Move to start of current line
[ENTER]	Move to start of next line

To move the cursor in character units:

[→]	Move right one character
[←]	Move left one character
[⇆]	Move right to start of next column (columns start at multiples of 10)
[⇧] [⇆]	Move left to start of previous column

To edit a line:

[F1]	Insert a line above the current line
[F2]	Delete the current line

To edit a character:

[Ins]	Insert a blank character
[Del]	Delete a character
[F4]	Character repeat mode toggle switch; when this switch is on, you can repeat a character by pressing the arrow keys

*RBEDIT displays 23 lines at a time on the screen.

If you enter these command lines

```
NEWPAGE
OPEN compuco
SELECT ALL FROM salesrep
```

Your screen will appear as:

```
                                                  <4, 1> [ESC] to exit
NEWPAGE
OPEN compuco
SELECT ALL FROM salesrep
```

Now press [ESC].

RBEDIT displays this menu:

```
---Edit again---Save file---Next file---Quit--------------------R:base screen editor
```

- Select *Edit Again* if you want to change the file you were just editing
- Select *Save File* to save the file you were just editing on disk
- Select *Next File* to get prompted for the name of a new file to edit
- Select *Quit* to return to either the R> prompt or the R:base main menu

Move the cursor to the *Save file* option and press [ENTER].

RBEDIT prompts you for a file name. (The filename can be preceded by a drive designator and a path.) For example, enter *exp.cmd* to save the command file under that file name in the current directory on the default drive.

```
---Edit again---Save file---Next file---Quit--------------------R:base screen editor
Name of new file to save:exp.cmd
```

After saving the file, RBEDIT displays the following menu:

```
----Old file---New File---Quit-----------------------------R:base screen editor
```

Move the cursor to the *Quit* option and press [ENTER].

NOTE: RBEDIT IS USED FOR THIS CLASS ONLY FOR DEMONSTRATION PURPOSES. THE FILE MUST BE ERASED FROM YOUR DISK. IT IS PROPRIETARY!

CONVERSION FACTORS
U.S. Customary To Metric (approximate)

LENGTH: 1 inch = 25.4 mm (exact) 1 foot = 304.8 mm (exact) 1 yard = 0.9144 m (exact) 1 mile = 1.609 km	VOLUME:* 1 cubic inch = 16.39 cm^3 1 cubic foot = 0.0283 m^3 1 cubic yard = 0.7646 m^3 1 fluid ounce = 29.57 ml 1 fluid quart = 0.946 l 1 gallon = 3.785 l
AREA: 1 square inch = 6.452 cm^2 1 square foot = 0.0929 m^2 1 square yard = 0.8361 m^2 1 acre = 0.4047 ha 1 square mile = 2.590 km^2	MASS: 1 ounce (av) = 28.35 g 1 pound (av) = 0.4536 kg 1 ton (2000 lb) = 0.9072 t
TEMPERATURE: $\frac{°F - 32}{1.8}$ = degrees Celsius	ENERGY, WORK: 1 foot-pound = 1.356 J 1 kilocalorie = 4.185 kJ 1 Btu = 1.055 kJ
FORCE: 1 ounce force = 0.278 N 1 pound force = 4.448 N 1 kilogram force = 9.807 N	VELOCITY: 1 mile per hour = $\begin{cases} 0.447 \text{ m/s} \\ 1.609 \text{ km/h} \end{cases}$
POWER: 1 horsepower = 746 W	

METRIC-ENGLISH UNIT CONVERSION TABLE

[Read as follows: Dimension—metric unit (symbol) equals English equivalent].

Length—
1 meter (m) = 39.37 inches = 3.28 feet = 1.09 yards.
1 kilometer (km) = 0.62 miles.
1 millimeter (mm) = 0.03937 inches.
1 centimeter (cm) = 0.3937 inches.
1 micrometer (μm) = 3.937×10^{-5} = 10^4 A.

Area—
1 square meter (m^2) = 10.764 square feet = 1.196 square yards.
1 square kilometer (km^2) = .386 square miles = 247 acres.
1 square centimeter (cm^2) = 0.155 square inches.
1 square millimeter (mm^2) = 0.00155 square inches.
1 hectare (ha) = 2.471 acres.

Volume—
1 cubic meter (m^3) = 35.314 cubic feet = 1.3079 cubic yards.
1 cubic centimeter (cm^3) = 0.061 cubic inches.
1 liter (l) = 1.057 quarts = 0.264 gallons = 0.81×10^{-6} acre-feet.

Mass—
1 kilogram (kg) = 2.205 pounds.
1 gram (g) = 0.035 ounces = 15.43 grains.
1 milligram (mg) = 0.01543 grains.
1 tonne (t) = 0.984 ton (long) = 1.1023 ton (short).

Time—
second day (s day). year (yr or a).

Force—
1 newton (N) = 0.22481 pounds (weight) = 7.5 poundals.

Velocity, linear—
1 meter per second (m/s) = 3.28 feet per second.
1 millimeter per second (mm/s) = 0.00328 feet per second.
1 kilometer per second (km/s) = 2,237 miles per hour.
1 meter per second (m/s) = 2.237 miles per hour.

Velocity, angular—
radians per second (rad/s).

Flow Rate (volumetric)—
1 cubic meter per second (m^3/s) = 15,850 gallons per minute = 2,119 cubic feet per minute.
1 liter per second (l/s) = 15.85 gallons per minute.
1 cubic meter per day (m^3/d) = 0.183 gallons per minute.
1 cubic hectometer per day (hm^3/d) = 264.2 million gallons per day.
1 quinaria (Ancient Rome) = 0.47-0.48 liter per second.
1 U.S. gallon per minute (gpm) = 0.0631 liter per second = 5.45 m^3/day.
1 million U.S. gallons per day (mgd) = 43.8 liters per second = 3,785 m^3/day.
1 million Imperial gallons per day = 52.62 liters per seconc
1 billion U.S. gallons per day (bgd) = 3.785 hm^3/day.
1 cubic foot per second (cfs) = 449 gallons per minute (gpm) = 28.3 liters per second (l/s).
1 acre-foot per day = 14.3 liters per second (l/s).

Transmissivity—
1 square meter per day = 80.5 gallons per day per foot.

Viscosity—
poise = 1.45×10^{-5} pounds (weight) seconds/square inch

Pressure—
1 newton per square meter (N/m^2) = 0.00014 pounds per square inch.
1 kilonewton per square meter (kN/m^2) = 0.145 pounds per square inch.
1 kilogram (force) per square centimeter = 14.223 pound per square inch.

Temperature—
degrees Celsius (C) = (5F)/9 − 17.77.
degrees K = degrees C + 273.16.

Work, energy, quantity of heat—
1 joule (J) = 2.778×10^{-7} kilowatt-hours = 3.725×10 horsepower-hours = 0.73756 foot-pounds = 9.48×10 British thermal units.
1 kilojoule (kJ) = 2.778×10^{-4} kilowatt-hours.

Power—
watt (W). kilowatt (kW)
joule per second (J/s).

(Unless otherwise noted, all gallons are U.S. gallons.)

SI units

In these conversion tables, SI units are shown in blue type.

Where SI units differ from technical metric units, the conversions are given for both.

The following list details the main SI units and their symbols which are used throughout these tables.

Length

1 km	0.621371 mile
1 m	1.09361 yd 3.2808 ft
1 cm	0.393701 in
1 mm	0.03937 in
1 μm	39.3701 μin
1 mile	**1.60934 km**
1 yd	**0.9144 m**
1 ft	**0.3048 m**
1 in	**25.4 mm**
1 milli-in (thou)	**25.4 μm**
1 μin	**0.0254 μm**

Volume, capacity

1 m^3	1.30795 yd^3
1 dm^3 (litre)	0.03531 ft^3 0.21997 imp gal 1.7605 pint 0.2642 US gal
1 cm^3 (ml)	0.06102 in^3 0.0352 fl oz
1 litre (dm^3)	0.21997 imp gal 1.7605 pint
1 ml (cm^3)	0.0352 fl oz
1 yd^3	**0.76455 m^3**
1 ft^3	**28.3168 dm^3**
1 in^3	**16.3871 cm^3**
1 imp gal	**4.54609 dm^3**
1 US gal	**3.78541 dm^3**
1 pint	**0.56826 dm^3**
1 fl oz	**28.4131 cm^3**

Area

1 km^2 (100 hectares)	247.105 acres
1 hectare (ha)	2.47105 acres **10 000 m^2**
1 m^2	1.19599 yd^2
1 cm^2	0.155 in^2
1 mm^2	0.00155 in^2
1 mile^2	**2.58999 km^2**
1 acre (4840 yd^2)	**4046.86 m^2** 0.404686 ha
1 yd^2	**0.836127 m^2**
1 ft^2	**0.092903 m^2**
1 in^2	**645.16 mm^2**

Mass

1 tonne	**1000 kg** 0.98420 ton 2204.62 lb
1 kg	0.01968 cwt 2.20462 lb
1 g	0.03527 oz
1 ton	**1016.05 kg** 1.01605 tonne
1 cwt	**50.8023 kg**
1 lb	**0.45359 kg**
1 oz	**28.349 g**

Density

1 kg/m^3	1.686 lb/yd^3 0.06243 lb/ft^3
1 g/cm^3	62.4280 lb/ft^3
1 ton/yd^3	**1328.94 kg/m^3**
1 lb/yd^3	**0.593 kg/m^3**
1 lb/ft^3	**16.0185 kg/m^3**
1 lb/in^3	**27.6799 g/cm^3**

Power

1 hp	**745.700 W (J/s)**
1 ft lbf/s	**1.35582 W**

Force

1 N	0.10197 kgf 0.22481 lbf
1 kN	101.971 kgf 224.809 lbf
1 kgf	**9.80665 N** 2.20462 lbf
1 dyn	**10^{-5}N** 0.224809 x 10^{-5}lbf
1 lbf	**4.44822 N** 0.45359 kgf
1 tonf	**9.96402 kN** 1016.05 kgf

Pressure, stress

1 Pa (N/m^2)	0.01 mbar 0.000145 lbf/in^2
1 kPa (kN/m^2)	0.01 kgf/cm^2 10 mbar 20.885 lbf/ft^2 0.2953 in Hg
1 kgf/cm^2	**98.0665 kPa** 14.223 lbf/in^2
1 bar	**100 kPa** 14.5038 lbf/in^2
1 mbar	**100 Pa** 2.0885 lbf/ft^2
1 atm	**101.325 kPa** 14.6959 lbf/in^2
1 mm Hg (torr)	**133.322 Pa** 0.01934 lbf/in^2
1 mm H_2O	**9.80665 Pa** 0.001422 lbf/in^2
1 lbf/in^2	**6.89476 kPa** 0.07031 kgf/cm^2 68.9476 mbar
1 lbf/ft^2	**47.8803 Pa** 0.4788 mbar
1 tonf/ft^2	**107.252 kPa** 1.094 kgf/cm^2
1 in Hg	**3.38639 kPa** 0.491 lbf/in^2
1 ft H_2O	**2.98907 kPa** 0.030 kgf/cm^2 22.3997 mm Hg

Viscosity, dynamic

1 Pa s (N s/m^2)	0.0208854 lbf s/ft^2
1 cP (centipoise)	2.08854 × 10^{-5} lbf s/ft^2 **0.001 Pa s**
1 lbf s/ft^2	**47.8803 Pa s**
1 lb/ft s	1488.16 cP 1.48816 kg/m s

Viscosity, kinematic

1 m^2/s	10.7639 ft^2/s
1 cSt (centistokes)	5.58001 in^2/h **1 mm^2/s** **10^{-6} m^2/s**
1 ft^2/h	**0.092903 m^2/h** 25.8064 cSt
1 in^2/s	**645.16 mm^2/s** 645.16 cSt

Energy

1 MJ	0.277778 kWh
1 J	0.737562 ft lbf
1 kgf m	**9.80665 J** 7.23301 ft lbf
1 therm	**105.506 MJ**
1 kWh	**3.6 MJ**
1 Btu	**1.05506 kJ**

HOW TO USE THIS GUIDE

This guide is divided into sections covering:

General Operating Concepts of E-RHYM

Applications

~~Specific Operating Concepts of E-RHYM~~

~~General Input Requirements~~

Output

Instuctions for Using Personal Computer Version

~~Instructions for Using BLM Interactive Timesharing Version~~

References

Appendices

~~Glossary~~

~~Index~~

If you are unfamiliar with E-RHYM you should begin by reading the General Operating Concepts section. We suggest you next read the Applications section, followed by the General Input Requirements section. After reading these sections you should have enough background information to run the model. You should gather your input data together and assemble it in an organized manner. Plan to spend at least a day learning to use the model. Computer models are very new tools for most rangeland managers and like most anything new, it takes some learning and practice to operate them successfully.

Whenever possible, model output should be checked against field measured values, particularly soil water content. Model performance can be improved by some adjustment of the soil and vegetation parameters.

If you do have questions, contact the Service Center at 776-0151.

GENERAL OPERATING CONCEPTS OF E-RHYM

E-RHYM is a rangeland computer model that produces daily estimates of runoff, evaporation from soil, transpiration, and soil water content in up to 4 soil layers. Annual herbage yield at peak standing crop is estimated through a relationship with the ratio of calculated transpiration to potential transpiration. E-RHYM also estimates peakflow, drainage from the bottom of the soil layers, and snowpack. The model produces daily, yearly or monthly summaries based on the user's request.

Input requirements for E-RHYM include daily climate data for precipitation, temperature, and solar radiation; hydraulic properties for each soil layer; and, basic vegetation characteristics. Climate data can come from historical records or it can be stochastically generated. Soil hydraulic property data can be measured in the field or laboratory, or it can be estimated based on soil texture. Vegetation input variables are estimated based on knowledge of species growth characteristics for the plant or functional group of plants in question.

Figure 1 and the following narrative depict a typical daily cycle for the E-RHYM model in computing soil water and evapotranspiration estimates.

Daily precipitation, maximum and minimum temperature, and solar radiation values are read from the data base and if the temperature indicates snow, precipitation is stored as snowpack. Otherwise, the daily precipitation total is applied to the SCS runoff curve number method to calculate the amount of runoff.

The computed daily runoff is subtracted from the daily precipitation value. The remainder is available for addition to the soil water balance component of the model.

As the soil water balance component of the model operates, water is removed from the soil by evaporation, transpiration, and drainage through the soil layers (up to 4).

Soil water addition proceeds one soil layer at a time. If, for example, the water content of the surface layer exeeds field capacity, water is added to the next layer and so on until all available precipitation is accounted for. If all the soil layers are filled, excess water is counted as drainage.

Before the execution of the soil water removal routines, soil evaporation and transpiration potentials are calculated. Soil evaporation is limited to the top 12 inches of soil and the actual water evaporated is dependent on the time that has passed since the soil surface was last wet. Potential transpiration is calculated based on an estimate of the transpiring portion of the plant (Relative Growth Curve) and the relative proportion of roots in the

soil layers. (The user must supply the relative growth curve and root proportion prior to program execution.)

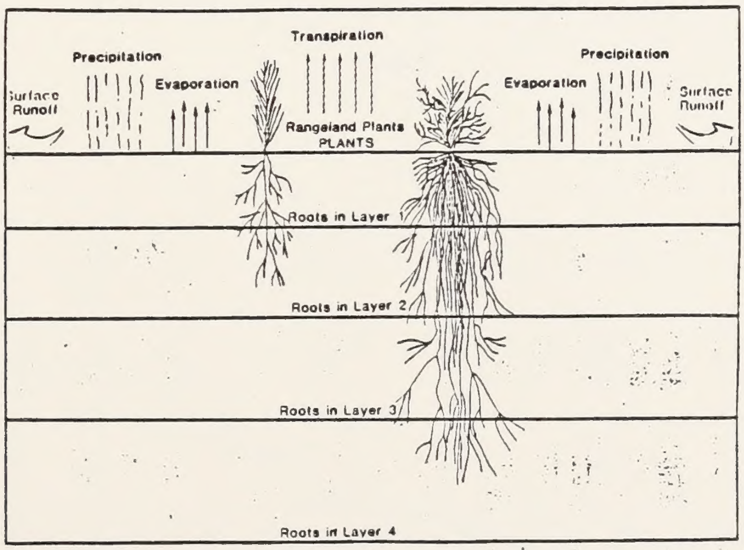
Soil water extraction begins at the first layer, first by evaporation, then by transpiration proceeding one layer at a time. If the surface soil layer cannot supply enough water to meet the daily potential transpiration demand (as constrained by the root system and stage of plant growth), the model extracts water from the second layer and so on until the demand is satisfied or until some soil water has been removed from all of the layers. When the potential transpiration demand cannot be met by a soil layer, the full demand is applied to the next layer but removal cannot exceed the full demand less the demand satisfied from the preceding soil layers.

The cycle is then repeated for each day.

When the estimated date of peak standing crop has been reached, the ratio of actual transpiration to potential transpiration is calculated as a climate index and can be multiplied by the site's yield potential to obtain the annual herbage yield at peak standing crop.

E-RHYM is currently available through an interactive computer program (one that asks you questions) on the Bureau of Land Management's Service Center computer.

E-RHYM is currently available in a BASIC language format, compatable with most personal computers supporting Microsoft-Disk Operating Systems .



TM MS-DOS is a trademark of the Microsoft Computer Corporation and does not imply product endorsement.

APPLICATIONS

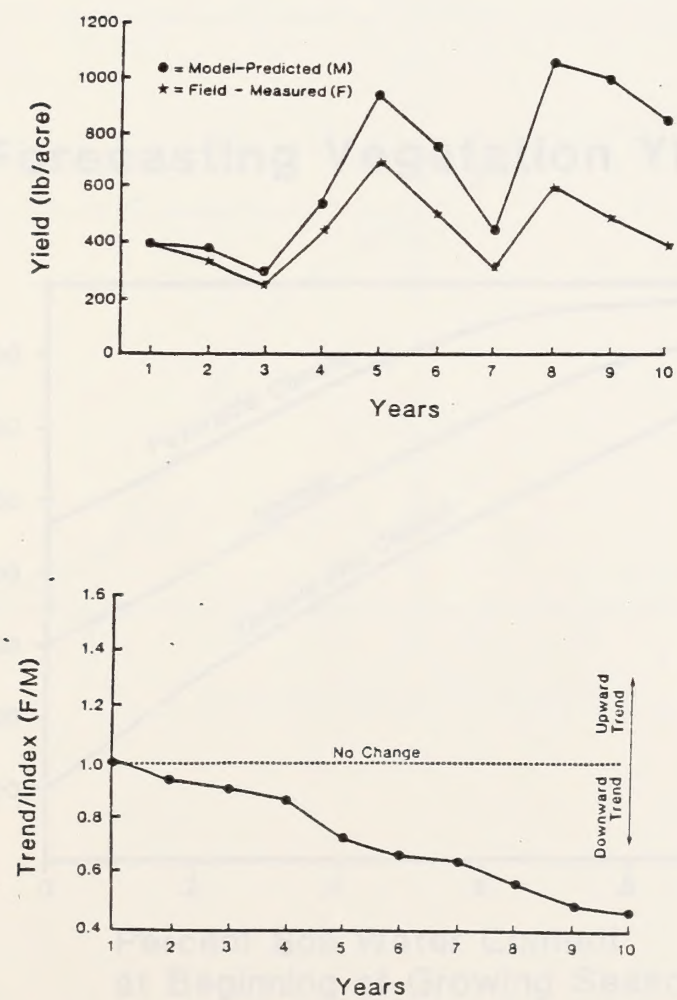
The model-calculated climate indice provides a index of the growing season climate as it relates to plant growth and enables comparisons of range treatments or vegetation inventories among years or range sites by accounting for a large portion of climate induced variation in plant response.

E-RHYM, calculates two climate indices, the "old" and the "new." The "old" indice is simply the ratio of cumulative transpiration (T) and potential transpiration (Tp). The "new" yield indice is calculated as the ratio of the area under the plotted seasonal, cumulative T and T_p curves, as in the Figure 2 below. Calculation of the "new" yield indice is based on the T and T_p for the period each year between the start of the growing season (STRGRO) and PSCDAY. The "new" indice appears to be correlated a little closer to peak standing crop yields than the "old" indice.

Use in Monitoring

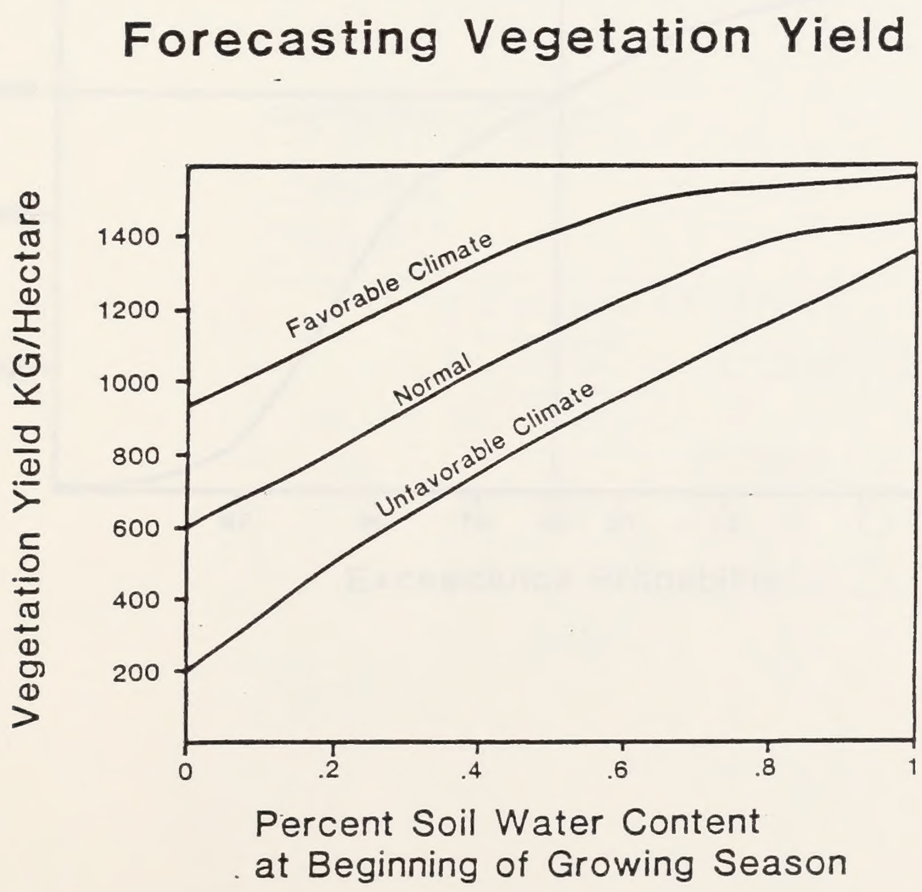
Model predicted results can be used with actual monitoring data. Figure 3a represents fild measured and model predicted yields. The ratios of field and model predicted yields are plotted in Figure 3b. Since the variability of model predicted yields represent only those produced by the climate, subsequent trend can be attributed to management assumming the model is accurately representing the yields.. This type of analysis is just one tool, when coulpled with sound professional judgement, can lead to better range management alternatives.

Climate vs. Management



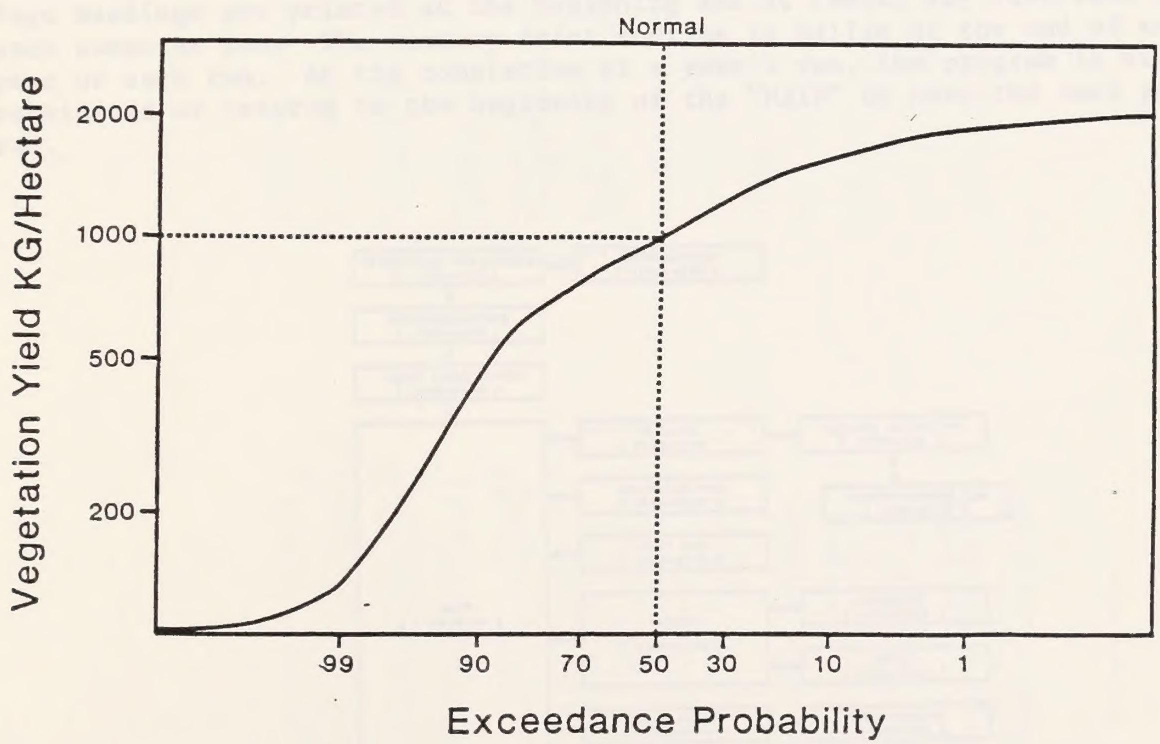
Use in Herbage Yield Forecasting

Output of the model can be used in a forecasting procedure developed by Wight and Hanson (1982) which utilizes long-term weather records. A population of site specific annual climate indices is generated using the current year's (forecast year) beginning soil water content and daily precipitation, solar radiation, and temperature data from past weather records for the remainder of the growing season. Each year of historical data generates a climate indice value. The generated populations of climate indices are usually normally distributed, and population means and standard deviations can be calculated and used to make probability forecasts. Forecasts can be periodically updated throughout the growing season by utilizing the current year's daily precipitation and mean temperature data up to the date of forecast and historical data for the remainder of the growing season. A similar procedure could be used to forecast runoff. An example is given in the Figure 4a.



A similar application is shown in Figure 4b. A number of E-RHYM runs can be made using historic climate records and the subsequent yields can be plotted to generate a long-term vegetation yield probability curve. This technique can improve range site descriptions where little vegetation information exists.

Long-term Vegetation Yield Probability Curve

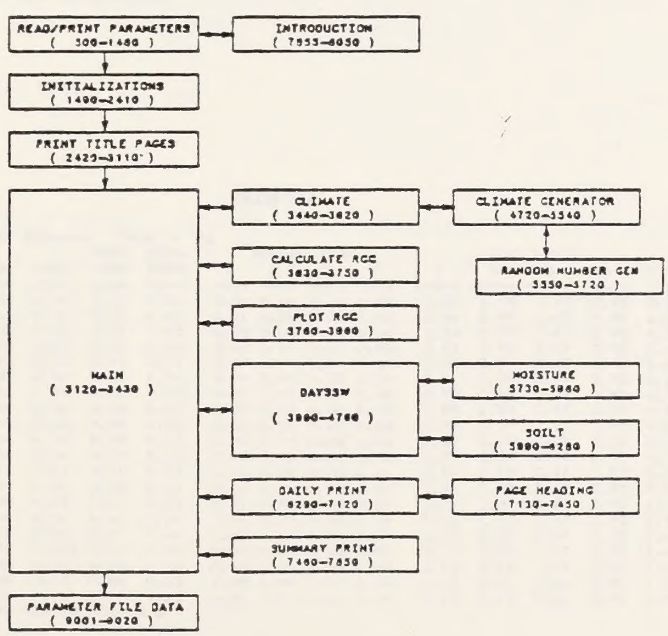


INSTRUCTIONS FOR USING PERSONAL COMPUTER VERSION

STRUCTURE

The structure of the model is diagrammed in Figure 9. E-RHYM requires two files to operate. One file contains the BASIC instruction code which also contains the site description variables. The second file contains the climate data. The program begins by reading and displaying the input parameters. The display of the site variables enables a quick check for accuracy. Following the initialization and title page display the program enters the "MAIN" section of the model. The climate component is called from the "MAIN" section, and a climate file is read through to the end of the year and internally stored in an array. If the climate file is lacking either air temperature and/or solar radiation data, a stochastic climate generating routine program is required to complete the year's record. After the current year's climate has been stored in arrays, a relative growth curve which depicts optimum plant activity is calculated and plotted.

A daily soil water balance is calculated by the "DAYSSW" component which receives snowmelt and runoff calculations from "MOISTURE" and calculated soil temperatures from "SOILT". The daily print routine is called from the "MAIN". Page headings are printed at the beginning and at twenty day intervals during each computer run. The summary print routine is called at the end of each year or each run. At the completion of a year's run, the program is either terminated or returns to the beginning of the "MAIN" to make the next year's run.



OUTPUT

Output formats shown in Figure 10 are available. The first format (Figure 10a) emphasizes hydrology, the second evapotranspiration (Figure 10b). These formats are specified on data input line 2 (statement number 9002) as shown in Figure 11.

Table 6. Examples of the two daily printout options.

PRTOPT=1

****TEST RUN**** YEAR = 76

DAY	TEMP	PREC	ROFF	PEAK	SNOW	POTENTIAL EVAP	POTENTIAL TRAN	ACTUAL EVAP	ACTUAL TRAN	SOIL WATER 1	SOIL WATER 2	SOIL WATER 3+4
81	22	0.00	0.00	0.00	0.00	.00	.00	.00	.00	2.83	3.00	6.42
82	15	0.03S	0.00	0.00	0.03	.00	.00	.00	.00	2.83	3.00	6.42
83	20	0.00	0.00	0.00	0.03	.00	.00	.00	.00	2.93	3.00	6.42
84	22	0.15S	0.00	0.00	0.18	.00	.00	.00	.00	2.63	3.00	6.42
85	28	0.00	0.00	0.00	0.18	.00	.00	.00	.00	2.83	3.00	6.42
86	29	0.03S	0.00	0.00	0.20	.01	.00	.01	.00	2.83	3.00	6.42
87	24	0.03S	0.00	0.00	0.23	.00	.00	.00	.00	2.83	3.00	6.42
88	29	0.15S	0.00	0.00	0.37	.01	.00	.01	.00	2.93	3.00	6.42
89	27	0.00	0.00	0.00	0.37	.00	.00	.00	.00	2.83	3.00	6.42
90	23	0.00	0.00	0.00	0.37	.00	.00	.00	.00	2.83	3.00	6.42
91	34	0.00	0.00	0.00	0.12	.02	.00	.01	.00	3.07	3.00	6.42
92	33	0.00	0.00	0.00	0.02	.02	.00	.01	.00	3.15	3.00	6.42
93	32	0.00	0.00	0.00	0.02	.02	.00	.01	.00	3.15	3.00	6.42
94	36	0.00	0.00	0.00	0.00	.03	.01	.01	.01	3.15	3.00	6.42
95	41	0.00	0.00	0.00	0.00	.05	.01	.02	.01	3.12	3.00	6.42
96	41	0.00	0.00	0.00	0.00	.05	.01	.02	.01	3.09	3.00	6.42
97	40	0.02	0.00	0.00	0.00	.04	.01	.02	.01	3.08	3.00	6.42
98	32	0.00	0.00	0.00	0.00	.02	.00	.01	.00	3.07	3.00	6.42
99	37	0.03	0.00	0.00	0.00	.04	.01	.03	.01	3.06	3.00	6.42
100	49	0.00	0.00	0.00	0.00	.07	.02	.02	.02	3.03	3.00	6.42

PRESS ANY KEY TO CONTINUE

PRTOPT=2

****TEST RUN**** YEAR = 76

DAY	ED	PREC	POTN TRAN	ACTU EVAP	ACTUAL TRAN 1	ACTUAL TRAN 2	ACTUAL TRAN 3	ACTUAL TRAN 4	SOIL WATER 1	SOIL WATER 2	SOIL WATER 3	SOIL WATER 4	T/TP
100	0.07	0.00	0.01	0.01	0.01	0.00	0.00	0.00	2.87	2.99	3.47	2.95	0.84
101	0.11	0.00	0.01	0.02	0.01	0.00	0.00	0.00	2.84	2.99	3.47	2.95	0.83
102	0.05	0.03	0.01	0.03	0.00	0.00	0.00	0.00	2.84	2.99	3.47	2.95	0.83
103	0.04	0.02	0.00	0.02	0.00	0.00	0.00	0.00	2.84	2.99	3.47	2.95	0.83
104	0.05	0.00	0.01	0.01	0.00	0.00	0.00	0.00	2.83	2.99	3.47	2.95	0.82
105	0.05	0.00	0.01	0.01	0.00	0.00	0.00	0.00	2.81	2.99	3.47	2.95	0.80
106	0.02	0.19	0.00	0.02	0.00	0.00	0.00	0.00	2.98	2.99	3.47	2.95	0.91
107	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	2.98	2.99	3.47	2.95	0.89
108	0.05	0.00	0.00	0.02	0.00	0.00	0.00	0.00	2.96	2.99	3.47	2.95	0.87
109	0.04	0.10	0.00	0.03	0.00	0.00	0.00	0.00	3.02	2.99	3.47	2.95	0.91
110	0.06	0.00	0.01	0.03	0.00	0.00	0.00	0.00	2.99	2.99	3.47	2.95	0.89
111	0.07	0.02	0.01	0.03	0.01	0.00	0.00	0.00	2.97	2.99	3.47	2.95	0.69
112	0.04	0.00	0.00	0.01	0.00	0.00	0.00	0.00	2.96	2.99	3.47	2.95	0.87
113	0.05	0.39	0.01	0.03	0.01	0.00	0.00	0.00	3.21	3.07	3.47	2.95	1.00
114	0.08	0.00	0.01	0.04	0.01	0.00	0.00	0.00	3.16	3.07	3.47	2.95	1.00
115	0.11	0.04	0.01	0.04	0.01	0.00	0.00	0.00	3.15	3.07	3.47	2.95	1.00
116	0.01	0.10S	0.00	0.01	0.00	0.00	0.00	0.00	3.15	3.07	3.47	2.95	1.00
117	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.15	3.07	3.47	2.95	1.00
118	0.04	0.23	0.00	0.03	0.00	0.00	0.00	0.00	3.23	3.11	3.60	2.95	1.00
119	0.06	0.00	0.01	0.03	0.01	0.00	0.00	0.00	3.18	3.11	3.60	2.95	1.00

PRESS ANY KEY TO CONTINUE

INPUT DATA

Climate data

The user must supply daily climate data for the E-RHYM model to function. The climate data must be available in a file accessable to the model. E-RHYM will request the file name of the climate data file during program execution.

There are several options for making the climate data available to E-RHYM.

Option 1. Enter the data from the keyboard and create the climate file prior to running E-RHYM. Use the CLIMENT program. (See Appendix 2). This program lets you input one or all of the required climate parameters and places them in the proper format for use by E-RHYM.

Option 2. Obtain the climate data preformatted from the Service Center. (See Appendix 2).

Option 3. Use the CLIMDAT climate support package (see Appendix 2) to obtain the following:

- Climate records of five year length from selected NOAA stations on or near BLM lands.
- A complete climate record from incomplete, user supplied data.
- A stochastically generated climate record statistically representative of actual long-term data for your site.
- Climate reports and statistics.

Site Input Parameters

Input parameters for this model are readily obtainable from soil surveys, field observations, and the included tables and figures. The parameter data are stored in the data statement numbers 9001 to 9020, Figure 11. These line numbers coincide with the lines 1 through 20 in the parameter display and the following listing of input parameters. See "Making a run" for changing data.

An example of the parameter file input.

```
9001 DATA TEST RUN
9002 DATA 1,1,2
9003 DATA 76,76,81,200
9004 DATA 4,.56,0
9005 DATA 9,9,12,12
9006 DATA 1.2,1.28,1.43,1.21
9007 DATA .03,.07,.08,.12
9008 DATA .27,.28,.22,.231
9009 DATA .31,.29,.25,.35
9010 DATA .17,.13,.17,.23
9011 DATA .8,.44,90,200
9012 DATA 1.0,.8,.3,.1
9013 DATA -20,150,15,1,.3
9014 DATA 10,.12,2,65,.2
9015 DATA 1,1,43.7,0,.70
9016 DATA 9,111,561,1001
9017 DATA 62.5,26,.155,-.085,56.5,37.5
9018 DATA 17,.225,-.145,430,285,288
9019 DATA 27.5,32.8,34.7,40.1,49.1,58.2
```

MAKING A RUN

This section describes the specific procedures for making a run. Follow the steps below.

Step	Instruction

1. Load the MS-DOS (disk operating system). This step varies with the type of computer you have, refer to computer manual or better yet, ask someone. Examples of some procedures are:

   Insert diskette containing COMMAND.COM and turn on computer.

   Computer with permanent disk storage (hard). Turn on computer.

2. After MS-DOS is loaded, make sure that it is referencing the floppy disk drive you intend to use. Usually disk A or B. The computer displays a :A or :B. To change the designation, simply type :A and press the return key, the computer should now display :A/.

3. Place the E-RHYM diskette in the specified drive and type BASICA and press the return key. An ok should appear on the screen.

4. Now type LOAD"ERHYM2" and press the return key. The disk drive should whirr for about 20 seconds.

5. Now type LIST 9000:9014 and press the return. Program statements should appear as in Figure 11, above.

6. To change the parameters displayed, simply type the statement line number. Then move the cursor over the data to be replaced and type in the new data then press return when you are finished.

7. Repeat step 6 for each statement number in which you need change input parameters.

8. Now you can run the program by typing RUN and return, or you can save your changes on another diskette by inserting a new formatted diskette and typing SAVE"filename" and return, where filename is the name of the file you want to save the altered ERHYM program.

9. Once you enter RUN and return, the disk drive will whirr and in about 20 seconds you will be asked for the name of the climate data file. After receiving the climate data the input parameters will be displayed on the screen. If you want to make a printed copy, use the Screen Print key or command for your particular system. After the input data has been displayed, ERHYM will begin executing the daily calculations. A RGC curve will be displayed and your output data will begin to start appearing on the screen.

10. Use the print screen key on your PC to obtain a hard copy of the display.

MAKING A RUN

This section describes the specific procedures for making a run following the steps below.

Step	Instruction

1. Bring the MIMOSA [illegible] up on your computer. This step varies with the type of computer you have, refer to computer manual or helper if necessary. Elements of some procedures are
   Insert diskette containing PROGRAM.*** and turn on computer
   Computer with permanent file storage (hard): Turn on computer

2. After MIMOSA is loaded, make sure that it is communicating the floppy disk drive you intend to use. Usually this A or B. The computer displays A> or B>. To change the communication, simply type A: and press the return key; the computer should now display A>.

3. Place the MIMOSA diskette in the specified drive and type BASICA and press the return key, which should appear on the screen.

4. Now type LOAD"MIMOSA" and press the return key. The disk drive should whirr for about 20 seconds.

5. Now type LIST 5000-5010 and press the return. Program statements should appear as in Figure 11, above.

6. To change the parameters (location, etc.), type the statement line number. Then move the cursor over the data to be replaced and type in the new data, then press return when you are finished.

7. Repeat step 6 for each statement number in which you want change input parameters.

8. Now you can save your program by typing SAVE and return. Or you can save your changes on another diskette by inserting a new (formatted) diskette and typing SAVE"filename" and return, where filename is the name of the file you want to save, with at least one letter.

9. Type RUN and press return. The disk drive will whirr for about 20 seconds. You will be asked for the name of the results data file. After answering, the program will run. The input parameters will be displayed on the screen. If you want to change a parameter, type the number and press return. If you are satisfied, type return. After the input has been displayed, the run will begin calculating the [illegible] calculations. A [illegible] will be displayed when [illegible] is complete and will begin to print results on the printer.

10. Use the print screen key to obtain a hard copy of the display.

Figure 12 is an example of the model output from which the parameter file, Figure 11 can be checked.

An example of the model output of the parameter file.

```
RUN
CHECK PARAMETER FILE

LINE-1                  ******* TEST RUN ********

                        1          2          2
LINE - 2              PRTOPT     DAYOPT     LOPT

                        76         76         81         200
LINE - 3              STARTY     ENDY       STRDAY     ENDDAY

                        4.00       0.36       0.00
LINE - 4              SLARES     AIRDRY     FURCAP

                               SOIL LAYERS
                        1          2          3          4
LINE - 5     THK        9.00       9.00       12.00      12.00
LINE - 6     BDENST     1.20       1.28       1.43       1.21
LINE - 7     ROCKF      0.03       0.07       0.08       0.12
LINE - 8     INITSM     0.27       0.28       0.22       0.23
LINE - 9     MMC        0.31       0.29       0.25       0.33
LINE - 10     UNASM     0.17       0.13       0.17       0.23

PRESS ANY KEY TO CONTINUE
                 ---------VEGETATION PARAMETERS---------

                  0.80       0.44       90.00      200.00
LINE - 11         CROPCO     TRANCO     STRGRO     ENDGRO

                  1.00       0.80       0.30       0.10
LINE - 12         ROOTF1     ROOTF2     ROOTF3     ROOTF4

                  -20.00     150.00     13.00      1.00       0.30
LINE - 13         STRRGC     PSCDAY     CSHAPE     DSHAPE     RGCMIN

PRESS ANY KEY TO CONTINUE
                 ---------WATERSHED/CLIMATE PARAMETERS---------

                  10.00      0.12       2.00       63.00      0.20
LINE - 14         DACRES     CS         LW         CN2        SIA

                  1.00       1.00       43.70      0.00       0.70
LINE - 15         TEMOPT     SOLOPT     XLAT       DEL        STWF

                  9          111        361        1001
LINE - 16         KSEED1     KSEED2     KSEED3     KSEED4

                62.500     26.000     0.155     -0.093     56.500     37.500
LINE - 17        TXMD       ATX        CVTX      ACVTX      TXMW       TN

                17.000     0.223     -0.145     430.000    283.000    283.000
LINE - 18        AOTN       CVTN      ACVTN      RMD        AR         RMW

                27.50      32.00      34.70      40.10      49.10      58.20
LINE - 19        JAN        FEB        MAR        APR        MAY        JUN

                67.30      67.20      57.20      46.70      33.10      28.80
LINE - 20        JUL        AUG        SEP        OCT        NOV        DEC
PRESS ANY KEY TO CONTINUE
```

Following is a description of each input parameter shown in Figures 11 and 12.

Line 1 TITLE

TITLE One line containing characters of alphanumeric information to be printed at the beginning of the output.

Line 2 PRTOPT, DAYOPT, LOPT

PRTOPT 1 - Output option that emphasizes hydrology (Figure 10a).
2 - Output option that emphasizes ET (Figure 10b).

DAYOPT 1 - Daily printout.
2 - Yearly summary printout only with a graph of the daily T/T_p values.

LOPT 1 - Inputs and outputs are in centimeters.
2 - Inputs and outputs are in inches.
3 - Precipitation input is in inches, and other inputs and outputs are in centimeters.

Line 3 STARTY, ENDY, STRDAY, ENDDAY

STARTY The last two digits of the first year of this run, for example, 72.

ENDY The last two digits of the last year of this run, for example, 79.

STRDAY Julian day the model starts, for example, 74.

ENDDAY Julian day the model stops, for example, 180.

-----SOIL PARAMETERS-----

Line 4 SLARES, AIRDRY, FURCAP (one value per soil layer)

SLARES Number of soil layers, for example, soil horizons with active roots present. Maximum of four.

AIRDRY (One value in the same units as THK.) The amount of soil water (inches or cm) below permanent wilting which can evaporated, for example, 0.7 (See Table).

FURCAP Surface storage capacity of the contour furrows in linear units (inches or cm), for example, 1.4. Units should be the same as for THK (line 7).

Line 5 THK (one value per soil layer)

THK Thickness of each soil layer. If LOPT (line 2) equals 1 or 3, then these values are assumed to be in centimeters. If LOPT equals 2, then these values are assumed to be in inches. If surface soil layer exceeds 12 inches (30.5 cm), it should be divided and entered as two equal soil layers.

Line 6 BDENST (one value per soil layer)

The bulk density (grams per cubic centimeter for each soil layer, for example 1.3. (Can be estimated from Table .)

Line 7 ROCKF (one value per soil layer)

Rock content not included in gravimetric soil water sample and expressed as a decimal fraction (0.0 - 1.0) on a volumetric basis.

Line 8 INITSM (one value per soil layer)
The initial soil water content (percent by weight expressed as a decimal fraction) for each soil layer, for example, 0.27.

Line 9 MHC (one value per soil layer)
Soil water content (percent by weight expressed as a decimal fraction) at field capacity for each soil layer, for example, 0.35. (Percent by volume/bulk density = percent by weight.) (Can be estimated from Table 1.)

Line 10 UNASM (one value per soil layer)
Soil water content (percent by weight expressed as a decimal fraction) at permanent wilting for each soil, for example, 0.15. (Can be estimated from Table 1.)

Field capacity, permanent wilting, bulk density, and airdry values as related to soil texture (from Wight and Neff, 1983).

Texture	Computer code	Field capacity[1] Volumetric	Field capacity[1] Gravimetric	Permanent wilting[1] Volumetric	Permanent wilting[1] Gravimetric	Bulk density	Airdry[2]
		g/cm^3	g/g	g/cm^3	g/g	g/cm^3	Inches
Sand	020	0.091	0.061	0.033	0.022	1.49	0.34
Loamy sand	060	.125	.084	.055	.037	1.49	.40
Sandy loam	100	.207	.143	.095	.066	1.45	.48
Loam	130	.270	.190	.117	.082	1.42	.52
Silt loam	140	.330	.250	.133	.101	1.32	.56
Sandy clay loam	160	.255	.159	.148	.092	1.60	.60
Clay loam	170	.318	.224	.197	.139	1.42	.80
Silty clay loam	180	.366	.261	.208	.149	1.40	.83
Sandy clay	190	.337	.223	.239	.158	1.51	.92
Silty clay	200	.387	.280	.250	.181	1.38	1.00
Clay	210	.396	.285	.272	.196	1.39	1.00

[1] From Rawls et al. (1982).

[2] The amount of water in the top 12 inches of soil profile held at tensions greater than permanent wilting which can be removed by evaporation.

-----VEGETATION PARAMETERS-----

Line 11 CROPCO, TRANCO, STRGRO, ENDGRO

CROPCO Crop coefficient, for example, 0.85.

TRANCO Transpiration coefficient. Estimated from equation [5].

TRANCO= 0.0213 + 0.0162 [average site yield, lb/acre]$^{1/2}$

STRGRO Julian day the model begins to accumulate T and T_p for calculation of the "new" yield indice, for example 90 (used only with the "new" yield indice.)

ENDGRO Julian day growing season ends, for example 200 (used only for plotting T/T_p when DAYOPT = 2).

Line 12 ROOTF (one value per soil layer)

The relative root density expressed as a decimal fraction (0.0 - 1.0) relative to the surface soil layer which is always 1.0.

Line 13 STRRGC, PSCDAY, CHAPE, DSHAPE, RGCMIN

STRRGC The value along the Julian day scale used to obtain the desired RGC. It can be a negative number, for example -30.

PSCDAY Julian day of peak standing crop, for example, 180.

CSHAPE A shape parameter for left side of RGC, for example, 2.0.

DSHAPE A shape parameter for right side of RGC, for example, 2.0.

RGCMIN The minimum value that RGC can have during the entire year (must be between 0.0 and 1.0).

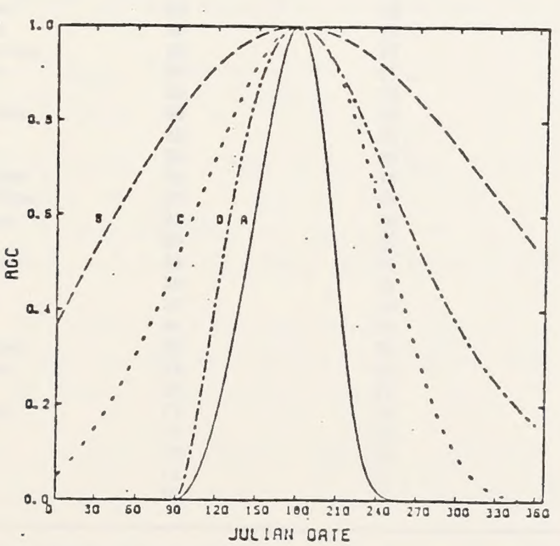


Figure 2. Examples of the relative growth curves (RGC) which can be described by equation [14]. The Julian day for peak standing crop (PSCDAY), start of the RGC (STRRGC), left side shape parameter (CSHAPE), and right side shape parameter (DSHAPE) for curves A, B, C, and D, respectively, are 182, 91, 2, and 5; 182, -120, 2, and 2; 182, -40, 2, and 5; and 182, 91, 2, and 1, respectively.

-----WATERSHED/CLIMATE PARAMETERS-----

Line 14 DACRE, CS, LW, CN2, SIA

DACRE Area of field in acres, for example, 3.2.

CS Channel slope (ft/ft), for example, 0.022.

LW Watershed length width ratio calculated by squaring length and dividing by watershed area, for example, 2.0.

CN2 Condition II SCS curve number, for example, 80.0 (can never be less than 30). (See Table 2 and Appendix 1.)

SIA Initial abstraction coefficient for SCS curve number, usually 0.20 (always input in inches).

.--Runoff curve numbers for range sites for the normal antecedent moisture condition, which is generally antecedent moisture condition II[1] (from Wight and Neff 1983).

Range site	Range condition: Fair	High-fair and good	Excellent
Wetland	95	95	95
Very shallow	95	90	85
Saline subirrigated	90	90	85
Subirrigated	90	90	85
Shale	90	85	80
Dense clay	90	85	80
Alkali clay	90	85	80
Saline upland[2]	90	85	80
Igneous	90	80	75
Shallow clayey[2]	85	80	75
Shallow sandy[2]	80	75	70
Shallow loamy[2]	80	75	70
Thin claypan	80	75	70
Shallow igneous	80	75	70
Steep clayey	80	75	70
Clayey[2]	80	75	65
Gravelly loamy	80	75	65
Steep loamy	80	75	65
Overflow	80	70	60
Loamy overflow	80	70	60
Clayey overflow	80	70	60
Coarse upland	80	70	60
Limy upland	80	70	60
Shallow breaks	80	70	60
Stony	80	70	60
Steep stony	80	70	60
Lowland	80	70	60
Saline lowland	80	70	60
Loamy lowland	80	65	55
Loamy	80	65	55
Sandy lowland	75	60	50
Sandy[2]	75	60	50
Gravelly	70	55	45
Sands	70	55	40
Choppy sands	70	55	40

[1] See USDA, Soil Conservation Service (1978).

[2] Range sites which were listed in USDA, Soil Conservation Service (1978) and were verified using watershed data from Hanson et al. (1981).

[3]This range site was not included in the Wyoming table. This is a South Dakota SCS range site designation.

-----WEATHER GENERATOR INPUTS------
see Appendix 2.

Line 15 TEMOPT, SOLOPT, XLAT, DEL, STWF

- TEMOPT
  - 0 - Daily maximum and minimum air temperatures are generated in WGEN subroutine.
  - 1 - Daily maxium and minimum air temperature are read from climate input file.
- SOLOPT
  - 0 - Solar radiation values are generated in WGEN subroutine.
  - 1 - Actual solar radiation values read from climate input file.
- XLAT The site latitude in degrees.
- DEL The difference in elevation (in feet) between site of model application and location of weather station from which climatic records were obtained for climate file or were used in climate generator.
- STWF A temperature weighting factor. It must have a value between 0.0 and 1.0 - usually about 0.70.

Line 16 K(1), K(2), K(3), K(4)

Seed numbers to initiate the random number generator routine. They must be odd integers with values greater than 100.

Line 17 TMXD, ATX, CVTX, ACVTX, TXMW, TN (See Figs. 4-9)

- TMXD The mean of t_{max} (dry), °F.
- ATX Amplitude of t_{max} (wet or dry), °F.
- CVTX Mean coefficient of variation of t_{max} (wet or dry), 'F.
- ACVTX Amplitude of coefficient of variation of t_{min} (wet or dry), °F.
- TXMW Mean of t_{max} (wet or dry), °F.
- TN Mean of t_{min} (wet or dry), °F.

Line 18 ATN, CVTN, ACVTN, RMD, AR, RMW (See Figs. 10-15)

- ATN Amplitude of t_{min} (wet or dry), °F.
- CVTN Mean of coefficient of variation of t_{min} (wet or dry), °F.
- ACVTN Amplitude of coefficient of variation of t_{min} (wet or dry), °F.
- RMD Mean of solar radiation (dry), ly.
- AR Amplitude of solar radiation (dry), ly.
- RMW Mean of solar radiation (wet), ly.

Line 19 TAO(1), TAO(2), TAO(3), TAO(4), TAO(5), TAO(6)

Mean monthly air temperature (°F) for January through June.

Line 20 TAO(7), TAO(8), TAO(9), TAO(10), TAO(11), TAO(12)

Mean monthly temperatures (°F) for June through December.

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APPENDIX 1

Table .--Runoff curve numbers for range sites for the normal antecedent moisture condition, which is generally antecedent moisture condition II[1] (from Wight and Neff 1983).

Range site	Range condition		
	Fair	High-fair and good	Excellent
Wetland	95	95	95
Very shallow	95	90	85
Saline subirrigated	90	90	85
Subirrigated	90	90	85
Shale	90	85	80
Dense clay	90	85	80
Alkali clay	90	85	80
Saline upland[2] S.D.	90	85	80
Igneous	90	80	75
Shallow clayey[2] S.D.	85	80	75
Shallow sandy	80	75	70
Shallow loamy[2] S.D.	80	75	70
Thin claypan	80	75	70
Shallow igneous	80	75	70
Steep clayey	80	75	70
Clayey[2] SD.	80	75	65
Gravelly loamy	80	75	65
Steep loamy	80	75	65
Overflow	80	70	60
Loamy overflow	80	70	60
Clayey overflow	80	70	60
Coarse upland	80	70	60
Limy upland	80	70	60
Shallow breaks	80	70	60
Stony	80	70	60
Steep stony	80	70	60
Lowland	80	70	60
Saline lowland	80	70	60
Loamy lowland	80	65	55
Loamy	80	65	55
Sandy lowland	75	60	50
Sandy[2] SD.	75	60	50
Gravelly	70	55	45
Sands	70	55	40
Choppy sands	70	55	40

[1] See USDA, Soil Conservation Service (1978).

Range sites which were listed in USDA, Soil Conservation Service (1978) and

APPENDIX 2

The R_s and maximum and minimum air temperature generating routines in SPUR (Wight 1983) have been added to ERHYM-II. These routines provide daily R_s and air temperature data as an option when such data are not available from local weather records. Model generated R_s is conditioned by actual daily precipitation values, thus reflecting daily variations in R_s. Generated R_s records are adequately similar to actual records so as to provide reliable results.

Generated air temperatures should be used with caution. The parameters for the climate generation routine (Figs.) are based on climatic data from weather stations throughout the United States, and often do not reflect the local elevational effects on air temperature. It would be appropriate to compare the generated air temperatures with local climate records before using them in the model. Table shows the effects of using generated temperature and R_s on some of the model outputs. Again, a word of caution; the data in Table 2 represents only one, relatively short simulation period.

Inputs for generating R_s and air temperature are described in the parameter section and parameter values are obtained in Figures 3 through 14. The BASIC program contains a random number generation generator by deleting program line 5210. On a "COMPAQ" computer, it takes about 8 minutes to generate one year of climate records.

When the air temperatures, either from weather records or from the climate generator, represent a site or location that is at an elevation different from which the model is being applied, average daily temperature (AVTEMP) is adjusted by the equation

$$AVTEMP = AVTEMP - (DEL * 0.00356) \quad [22]$$

where DEL is the difference in elevation between location of model application and location of the weather station from which the air temperatures were obtained or the location for which they were generated.

Wight, J. R., and C. L. Hanson. 1982. Forecasting yearly herbage production using historical climatic data with a conceptual range forage model. In Abstract of Papers, 35th Annual Meeting of the Society for Range Management, Calgary, Alberta, Canada, Feb. 8-12, 1982.

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Problem Set:

<u>Objective</u> To become familiar with flood frequency analysis and its use in design hydrology.

<u>General</u>

Hydraulic structures such as ditches, culverts, and bridges must be designed to resist certain size storm events. Information about probable extremes which proposed structures may be required to withstand and many other hydrologic problems can be solved by frequency analysis, using past records of peak flows and storm events.

The first step in a flood frequency analysis is to compile the data. If extreme events are of primary concern, the analysis most likely will use only the annual events, i.e., the maximum size event of each year. Such an analysis is termed annual series. An annual series, however, ignores second - and lower - order events of each year which may be greater magnitude than the largest events of other years. A partial duration series analysis overcomes this problem by using all events above a selected base. Commonly a partial series uses the <u>n</u> largest events in the period of record.

Frequency analysis labels the events which can be expected to occur, on an average, once every N years, the N-year event. This does not imply that such events will occur once every N-years. In fact, there is a 1% chance that the 100-year event will occur during any 365-day period.

After the data is compiled, events are ranked in decreasing order of size and assigned an order number <u>m</u>. The plotting formula most commonly used is

$$Tr = \frac{n + 1}{m}$$

where tr is the return period of an event, m is the order number of that event, and n is the number of years of record. The size of an event is then plotted over its return period and a straight line fitted through the plotted points. If we are studyng an annual series of peak flows, this plotting would be done on special paper called Gumbel probability paper. A partial series of peak flows requires semilog paper, and an annual series of rainfall data requires log-log paper. These types of paper will generally facilitate drawing the straight line through the data of each type of analysis.

The probability (p) of a certain-sized event being equaled or exceeded in the next year can be defined as the reciprocal of the return period

$$p = \frac{1}{Tr} \tag{2}$$

The probability of non-occurrence (q) is

$$q = 1 - p \tag{3}$$

and substituting (2) in (3) gives

This problem was prepared by R.L. Beschta of Oregon State University

$$q = \frac{Tr - 1}{Tr} \qquad (4)$$

However, return period indicates only the average interval between events equal to or greater than a certain size. We want to know the probability of an event with a certain return period occurring within a given time period. The probability P_n that a given event will be equaled or exceeded at least once in the next n years is the sum of the probabilities of occurrence for each year to the nth year and may be expressed

$$P_n = 1 - q^n \qquad (5)$$

Procedure

Complete Table 1 and plot data points on Figure 1. Fit a straight line through the data points by the ocular estimate (eyeball) method.

Problems

(1) Determine the probability that a 24-hour rainfall of 3.5 inches will be equaled or exceeded in the next year. (Hint: start by determining the return period of a 3.5-inch 24-hour storm).

(2) A structure has been designed to withstand a 25-year 24-hour storm. Determine the probability that the capacity of the structure will be equaled or exceeded during the next 30 years. (Hint: substitute equation 4 in equation 5.) Explain what this probability means.

(3) Let's assume we can accept no greater than a 25% chance of failure in the next 25 years. What would be the amount of 24-hour rainfall that we will design for?

Questions

1. What is return period or recurrence interval?

2. How far would you feel safe extending the line in Figure 1? Why?

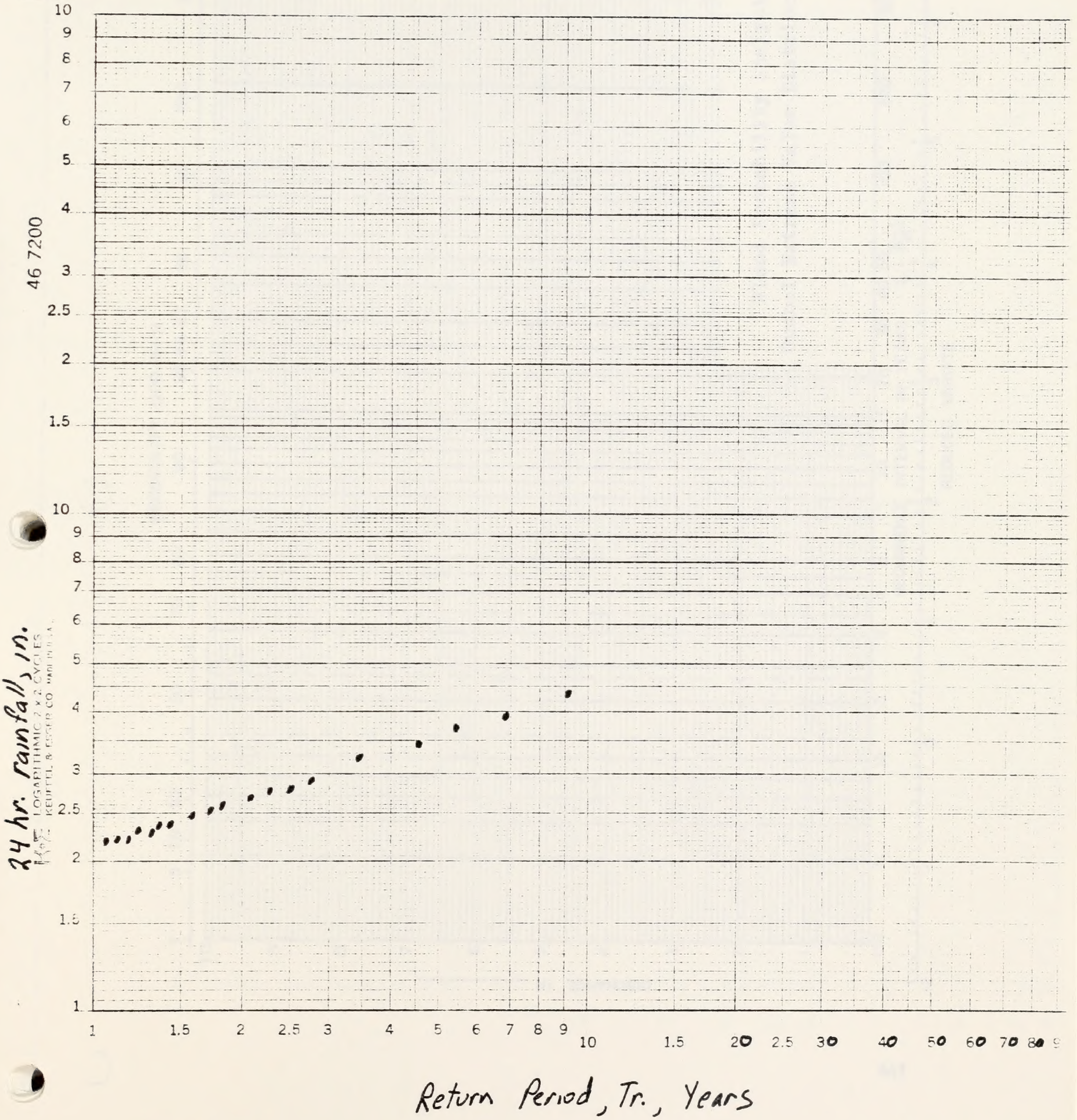
3. According to Table 1, the maximum 24-hour storm for the period of record was 6.01 inches and occurred in 1974. In the year 1997 we find this 6.01-inch 24-hour storm is still the largest event of the period of record. According to equation 1 it has a "new" return period of 50 years. How can this be?

Table 1. Maximum Annual 24-Hour Rainfall, Cloud Mountain, Colorado

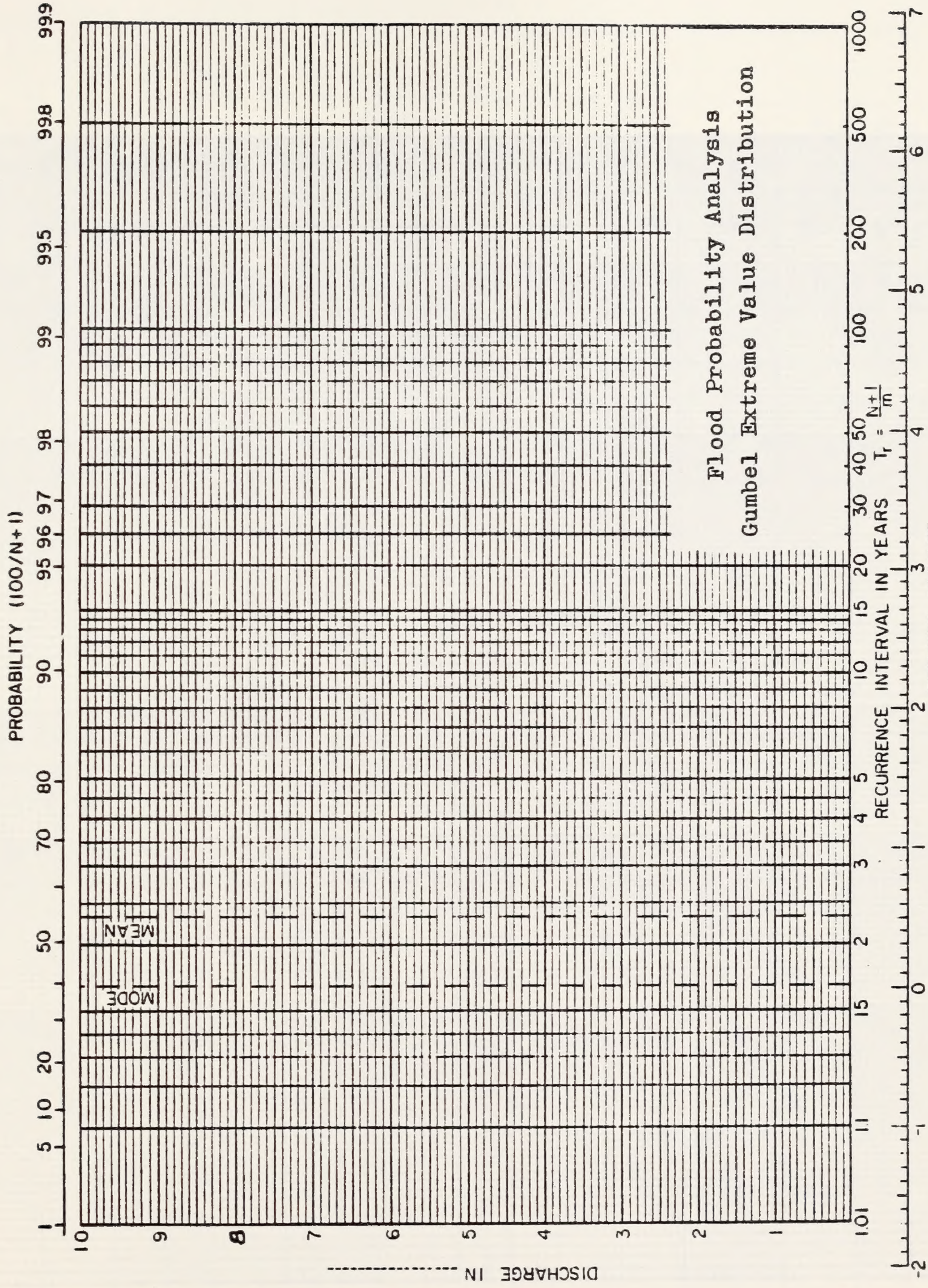
Year	24-Hour Rainfall (In.)	Order Number (M)	Return Period Tr (Years)
1949	3.19	8	3.38
1950	2.55	15	1.80
1951	2.86	10	2.70
1952	2.38	19	1.42
1953	3.35	6	4.50
1954	2.26	22	1.23
1955	2.75	11	2.45
1956	2.17	25	1.02
1957	3.85	4	6.75
1958	2.14	26	1.04
1959	3.22	7	3.86
1960	2.51	16	1.69
1961	2.45	17	1.59
1962	2.31	21	1.29
1963	2.74	12	2.25
1964	3.62	5	5.40
1965	4.39	3	9.00
1966	2.68	13	2.08
1967	2.20	23	1.17
1968	2.18	24	1.12
1969	2.60	14	
1970	3.09	9	
1971	2.39	18	
1972	4.85	2	
1973	2.35	20	
1974	6.01	1	

$$Tr = \frac{n+1}{m}$$

$n + 1 =$ ____



Cloud Mountain:
(Log - Log Paper)


Flood Probability Analysis
Gumbel Extreme Value Distribution
PROBABILITY (100/N+1)
1 5 10 20 50 70 80 90 95 96 97 98 99 99.5 99.8 99.9
RECURRENCE INTERVAL IN YEARS
1.01 1.1 1.5 2 3 4 5 10 15 20 30 40 50 100 200 500 1000
$T_r = \frac{N+1}{m}$
REDUCED VARIATE
-2 -1 0 1 2 3 4 5 6 7
DISCHARGE IN
1 2 3 4 5 6 7 8 9 10
MEAN
MODE

46 7200

K+E LOGARITHMIC 2 x 2 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

10 9 8 7 6 5 4 3 2.5 2 1.5 10 9 8 7 6 5 4 3 2.5 2 1.5 1

1 1.5 2 2.5 3 4 5 6 7 8 9 10 1.5 2 2.5 3 4 5 6 7 8 9 1

Table 10-28 Constructing a flood-frequency curve.

YEAR	ANNUAL PEAK DISCHARGE (IN/HR)	RANK (m)	RECURRENCE INTERVAL (YR) $T = \frac{n+1}{m}$	YEAR	ANNUAL PEAK DISCHARGE (IN/HR)	RANK (m)	RECURRENCE INTERVAL (YR) $T = \frac{n+1}{m}$
1937	0.15	8	4.0	1953	0.04	26	1.23
1938	0.05	20	1.6	1954	0.03	31	1.03
1939	0.04	23	1.39	1955	0.06	18	1.78
1940	0.07	15	2.1	1956	0.19	6	5.3
1941	0.08	14	2.3	1957	0.44	1	32.0
1942	0.03	30	1.07	1958	0.05	22	1.45
1943	0.07	16	2.0	1959	0.25	3	10.7
1944	0.04	24	1.33	1960	0.14	9	3.6
1945	0.21	5	6.4	1961	0.22	4	8.0
1946	0.13	10	3.2	1962	0.04	27	1.18
1947	0.07	17	1.88	1963	0.27	2	16.0
1948	0.09	12	2.7	1964	0.18	7	4.6
1949	0.04	25	1.28	1965	0.04	28	1.14
1950	0.09	13	2.5	1966	0.06	19	1.69
1951	0.05	21	1.52	1967	0.04	29	1.10
1952	0.12	11	2.9	Total $n = 31$			

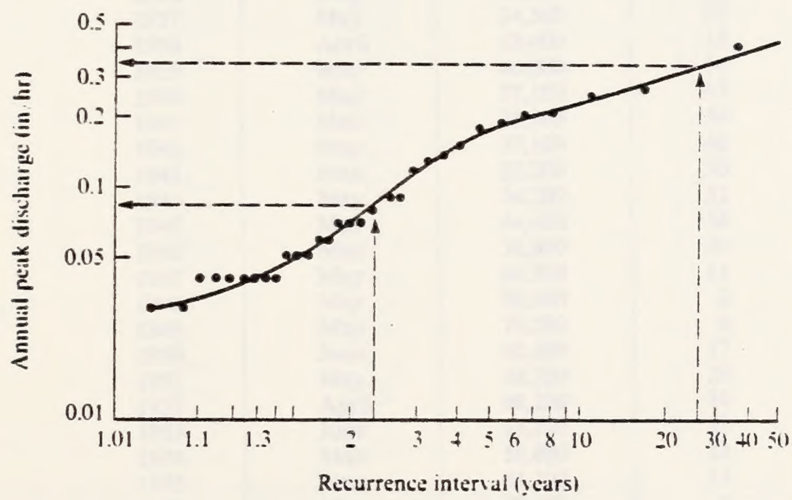


Figure 10-55 Plot of recurrence interval graph of annual peak discharge.

Table 11-6 FLOOD-PROBABILITY ANALYSIS FOR THE CLEARWATER RIVER AT KAMIAH, IDAHO
Drainage area = 4,850 mi^2 (12,560 km^2)

Year	Month	Discharge, ft^3/s	Order m	Plotting position, y
1911	June	39,500	45	1.24
1912	May	61,900	19	2.95
1913	May	76,600	5	11.20
1914	May	42,200	42	1.33
1915	May	28,200	55	1.02
1916	June	56,000	25	2.24
1917	June	70,500	10	5.60
1918	May	52,800	28	2.00
1919	May	52,000	31	1.81
1920	May	43,600	41	1.37
1921	May	69,700	12	4.67
1922	June	62,400	18	3.11
1923	May	49,600	32	1.75
1924	May	58,900	22	2.55
1925	May	59,800	20	2.80
1926	April	35,900	50	1.12
1927	June	68,600	13	4.31
1928	May	72,100	7	8.00
1929	May	52,700	29	1.93
1930	April	31,000	53	1.06
1931	May	40,800	43	1.30
1932	May	72,100	8	7.00
1933	June	81,400	3	18.67
1934	April	45,900	37	1.51
1935	May	44,000	40	1.40
1936	May	63,200	16	3.50
1937	May	34,300	51	1.10
1938	April	63,400	15	3.73
1939	May	46,000	36	1.56
1940	May	37,100	47	1.19
1941	May	28,900	54	1.04
1942	May	37,100	48	1.17
1943	May	52,200	30	1.87
1944	May	34,200	52	1.08
1945	May	44,400	38	1.47
1946	May	36,600	49	1.14
1947	May	69,900	11	5.09
1948	May	99,000	2	28.00
1949	May	76,200	6	9.33
1950	June	62,600	17	3.29
1951	May	44,200	39	1.44
1952	April	49,200	34	1.65
1953	June	53,100	27	2.07
1954	May	58,800	23	2.43
1955	June	64,100	14	4.00
1956	May	77,800	4	14.00
1957	May	71,200	9	6.22

Table 2.3 Plotting Position – Middle Fork Beargrass Creek, Cannons Lane, Louisville, Kentucky.

Year	Discharge	Rank	Plotting Position
1945	1810	9	0.281
1946	791	28	0.875
1947	839	27	0.844
1948	1750	10	0.313
1949	898	24	0.750
1950	2120	7	0.219
1951	1220	18	0.563
1952	1290	15	0.469
1953	768	29	0.906
1954	1570	11	0.344
1955	1240	17	0.531
1956	1060	21	0.656
1957	1490	12	0.375
1958	884	25	0.781
1959	1320	14	0.438
1960	3300	3	0.094
1961	2400	4	0.125
1962	976	22	0.688
1963	918	23	0.719
1964	3920	2	0.063
1965	1150	20	0.625
1966	874	26	0.813
1967	712	30	0.938
1968	1450	13	0.406
1969	707	31	0.969
1970	5200	1	0.031
1971	2150	6	0.188
1972	1170	19	0.594
1973	2080	8	0.250
1974	1250	16	0.500
1975	2270	5	0.156

DESIGN HYDROLOGY

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Flow-frequency, Probability, Risk Analysis

A statement of the probability of occurrence of rainfall of a certain magnitude is fundamental to the design of hydraulic structures. We are after the following:

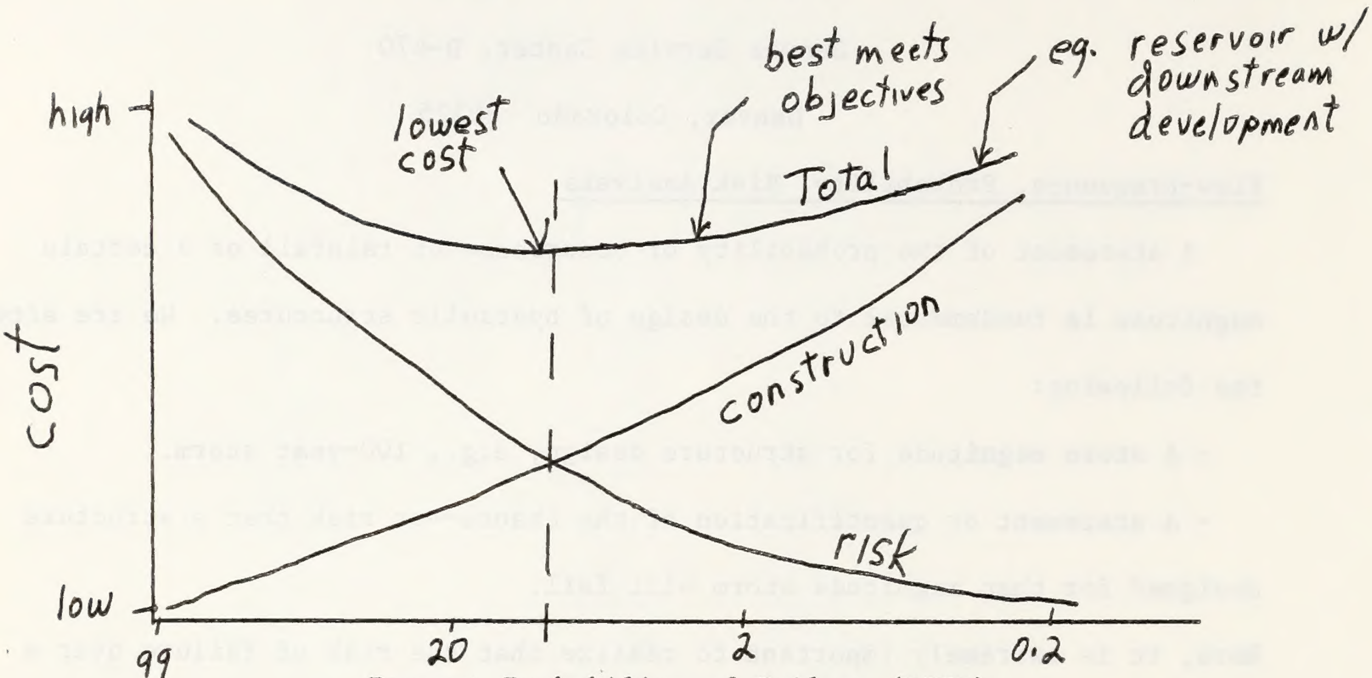
- A storm magnitude for structure design, e.g., 100-year storm.
- A statement or quantification of the chance--or risk that a structure designed for that magnitude storm will fail.

Here, it is extremely important to realize that the risk of failure over a project life is different than the probability of occurrence in any one year. We will discuss this later.

First, why do we need a quantification of risk?

1. It is a management consideration--e.g., safety, resource integrity, maintenance costs.
2. It is a cost consideration.
   - No structure is risk free.
   - The more risk free we make our designs, the higher the cost.

So, we need to optimize construction "costs" and risk costs.



Percent Probability of Failure (RISK)

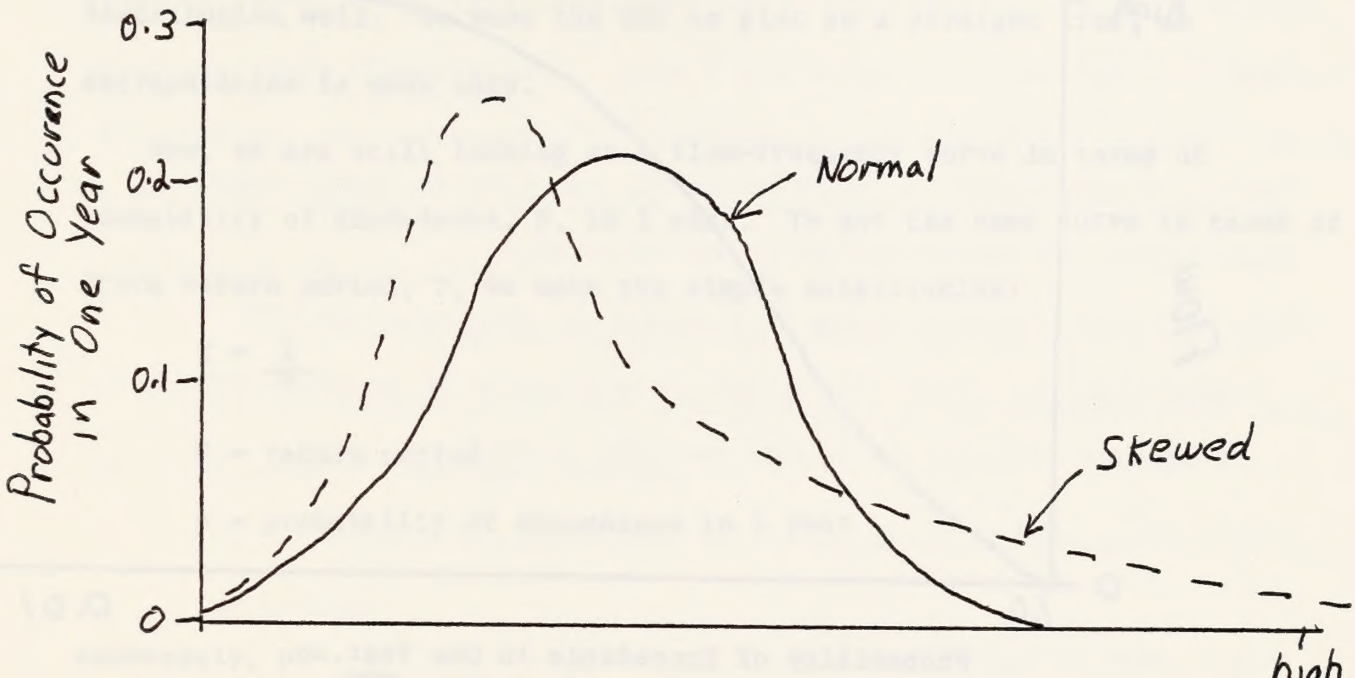
First step in design hydrology is to develop a flow-frequency (or storm-frequency) relationship, i.e., quantify storm size in terms of return period.

To do this, we first define either

- annual maximum series of, say, peak flows, i.e., the single largest flow of each year, or
- partial duration series of peak flows, i.e., all peak flows over a certain level (may be more than one per year; not much difference over ten-year flow).

A sufficiently large (20 years +) sample of annual peak flows will define a probability density function, or PDF.

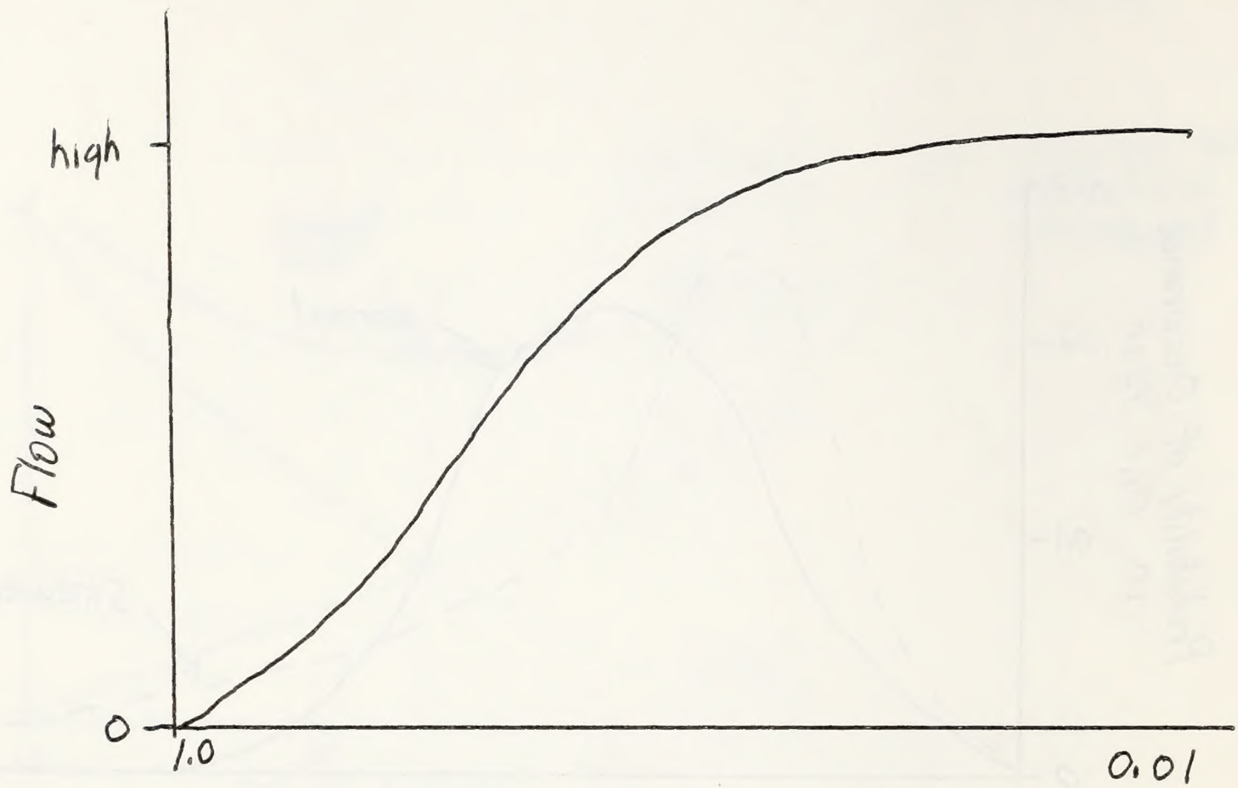
To define a PDF, we plot



A normal, or bell-shaped distribution is a common PDF. Streamflows, however, are usually highly skewed.

The probability that a flow greater than X will occur is equal to the area under the curve to the right of that flow. Conversely, the probability that a flow less than X will occur is equal to the area under the curve to the left of that flow. The total area under a PDF is 1.0.

This leads to the concept of a cumulative probability, the probability that a flow greater than X will occur, i.e., plot flow vs. cumulative probability, or area under the curve, to the right.



Probability of Exceedance in One Year, p

This is our basic flow frequency curve. The shape of the PDF determines the shape of the flow frequency curve.

- If the PDF is normal, we have the above.
- If the PDF is log normal, and we plot on log-normal probability paper, we get a straight line.

- There are other common skewed PDFs, including Gumbel Type I

  Gumbel Type III

  Log-Pearson III

Log-Pearson is simply a skewed distribution with a variable degree of skew, i.e., it is more flexible in accommodating these data. WRC recommends its use, but most peak flow series will fit a Gumbel or log-normal distribution well. We want the CDF to plot as a straight line, so extrapolation is made easy.

Now, we are still looking at a flow-frequency curve in terms of probability of exceedance, P, in 1 year. To get the same curve in terms of storm return period, T, we make the simple substitution:

$$T = \frac{1}{P}$$

T = return period

p = probability of exceedance in 1 year

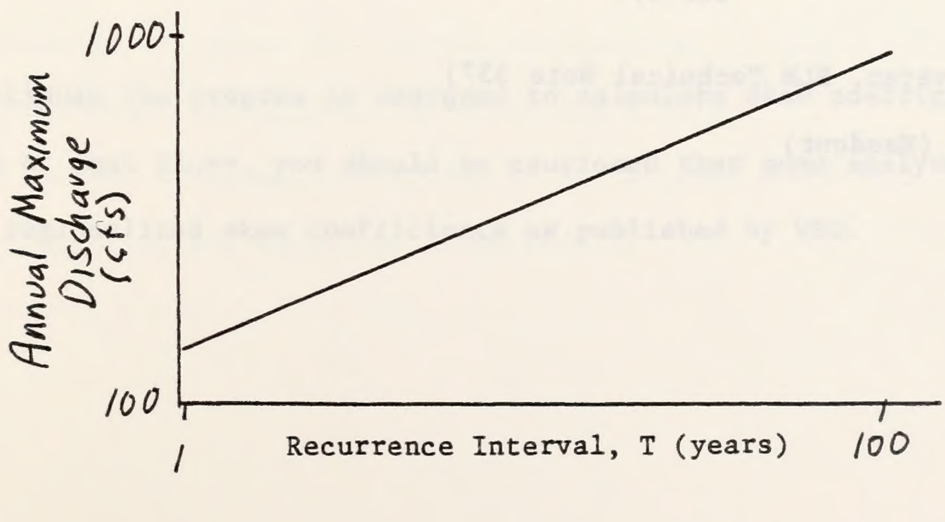
conversely, $p = \frac{1}{T}$

and the probability on non-occurrence--i.e., not having a flow greater than an amount

$$q = 1 - p$$
$$= 1 - \frac{1}{T}$$

Our final product is the traditional flow-frequency curve:

Exceedance Probability



Remember, the curve will only be straight if the PDF is the same as the kind of paper chosen.

To plot a flow-frequency curve, given an annual series of peak flows, we use

$$T = \frac{n + 1}{m}$$

where n is the number of years of record and m is the order number of the event within the entire series (order by size).

<u>Once the flow frequency curve is plotted, we can calculate RISK:</u>

where RISK, q, = the probability of exceedance of an event with a recurrence interval, T, within the next n years

$$q = 1 - \left(1 - \frac{1}{T}\right)^n$$

$$= 1 - \text{prob. of non-exceedance}$$

We can go one step further and look at the probability of experiencing more than one event of a certain T within an n year period

$$q = 1 - \left(1 - \frac{1}{T}\right)^n$$

$$= 1 - p^n$$

where $p = p^i \, (1-p)^{N-i} \quad \frac{N!}{i(N-i)!}$

(See Van Haveren, BLM Technical Note 337)

Problem set (Handout)

Flood Frequency: Log-Pearson III

The Log-Pearson III flood frequency distribution assumes that the logarithms of individual peak flows, when plotted as a probability density function (PDF), will fit a curve defined by Karl Pearson (actually a three parameter Gamma distribution). Like a log-normal distribution or a Gumbel III distribution, the Log-Pearson III distribution is positively skewed. The skew coefficient, however, is not fixed, but is related to the coefficient of variation of the data by:

$$\gamma = 3Cv + Cv^3$$

Therefore, defining a PDF and subsequently a flow-frequency curve using the Log-Pearson III methods requires:

1. Calculation of a coefficient of variation of the logarithms of the peak flows

$$(Cv = S/\overline{X})$$

2. Calculation of a skew coefficient from Cv

3. Selection of a "K" from a table given computed skew and recurrence interval

We will do the calculation using a computer program (Pearson).

Although the program is designed to calculate skew coefficient from a series of peak flows, you should be cautioned that some analyses are done using regionalized skew coefficients as published by WRC.

Rainfall-Runoff Modeling: The SCS Curve Number Method

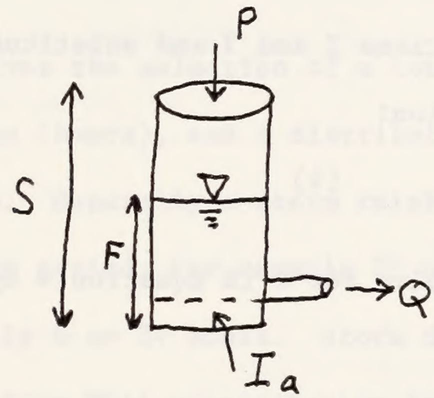
One of the most widely used and accepted methods of calculating runoff volume from rainstorms is the runoff curve number method developed by the Soil Conservation Service (SCS). The method has been expanded to calculate peak runoff rates and synthetic storm hydrographs. By assuming that design rainstorms produce runoff of the same return period, the method can be used to develop design flows for hydraulic design.

I will briefly review the theory and assumptions (and simplifications) embodied by the Curve Number Method, calculation procedures, sources of information, and selection of design storms. We will then solve some design hydrology problems using a computerized version of the procedure.

Background

The SCS Curve Number Method, conceptually, is a storm-period runoff model. It assumes that runoff does not begin upon the initiation of rainfall, but rather all rainfall up to a point is absorbed by the watershed, i.e., it is intercepted, infiltrated, or ponded. This is termed the initial rainfall

abstraction, I_a. Once I_a is satisfied, runoff begins, but so does additional watershed storage. In other words, I_a is less than the potential watershed storage, S.



Since S includes I_a, $S \geq I_a$.

In fact, analysis of hundreds of storms worth of data from dozens of watersheds suggests that

$I_a = 0.2S$ (1)

Therefore, once runoff, Q, has begun, it remains a fraction of the total precipitation, P, minus the initial abstraction, I_a (since we still contribute runoff to filling the remaining 0.8S).

So, actual watershed retention, F, for a given storm will always be less than or equal to the potential retention, S.

$F = (P-I_a) - Q$ (2)

SCS assumed the ratio of runoff to rainfall (minus I_a) was the same as the ratio of actual to potential storage. Or:

$$\frac{F}{S} = \frac{Q}{(P-I_a)} \qquad (3)$$

Thus, if all storage is full, Q = P. If lots of storage remains, $Q \ll P$. Intuitively, this seems ok.

If we combine Equations 2 and 3 and substitute 0.2S for I_a, we get the basic SCS runoff equation:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \qquad (4)$$

The SCS chose to solve for S in Equation 4 by using a runoff curve number (CN) where

$$S = \frac{1000}{CN} - 10 \qquad (5)$$

This way runoff goes up as the curve number goes up, and the curve number varies from 0 to 100.

Since CN represents S, which includes I_a, it, too, is a function of cover, land use, soil type, and antecedent soil moisture. Then all become factors in the selection of a curve number.

Curve Number Selection:

Curve number selection is based on hydrologic soil group, cover/land use, hydrologic condition, and antecedent soil moisture condition. Given information on those factors, CN selection is aided by available tables and graphs.

See Handouts:

- Hydrologic soil groups
- Antecedent moisture condition tables
- Curve number tables
- Rangeland curve number graph

Design Rainfall;

Design rainfall involves the selection of a total storm rainfall volume (inches), a storm duration (hours), and a distribution of storm intensities within the storm duration. Generally a storm rainfall amount is selected to represent a certain return period, for example 25 or 50 years, within a specified duration, usually 6 or 24 hours. Storm duration-frequency information is available from NOAA precipitation-frequency atlases, or can be calculated from local rain gauge data. If information on the distribution of storm intensities is available, it may be used. Otherwise, SCS has analyzed rain gauge data from across the country and generalized two representative intensity distributions--Type I and Type II. A Type I distribution is usually applicable on the western side of the Sierra-Cascade Mountains. The Type II distribution applies to the rest of the United States. In certain regions, localized distributions have been developed. For example, the Farmer-Fletcher distribution has been derived from precipitation data in northern Utah.

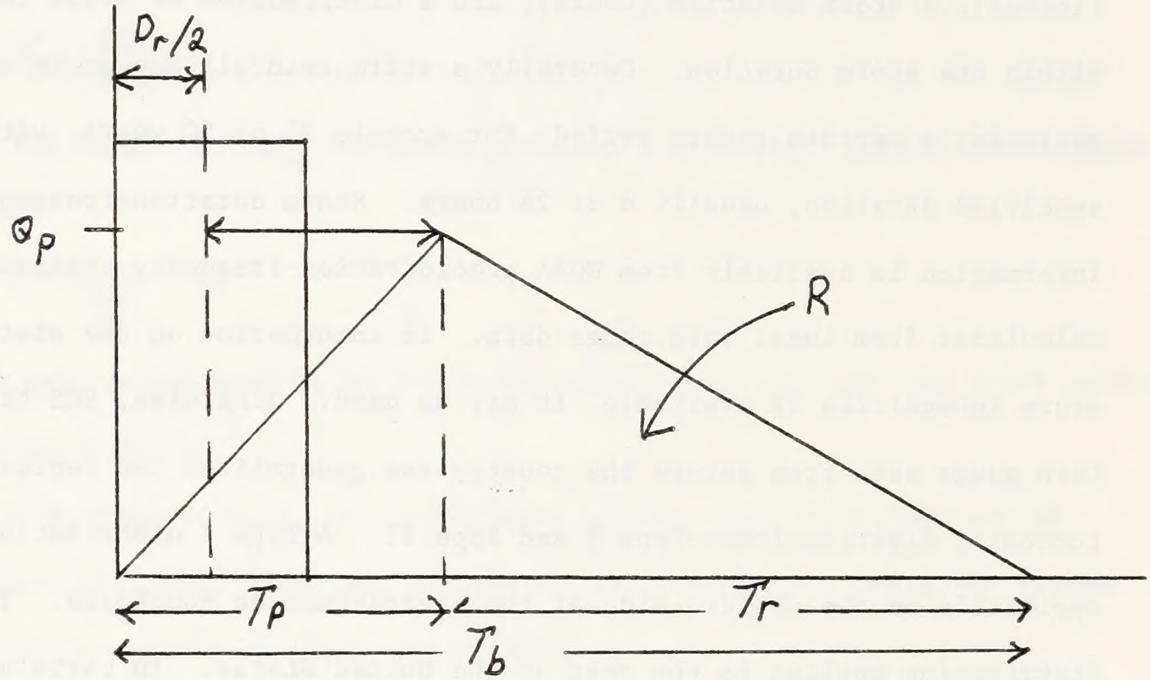
See Handout:

Type I and Type II distributions

Peak Flows and Synthetic Hydrographs

Synthetic hydrographs are constructed from unit hydrographs. A unit hydrograph represents one inch of runoff from a storm of a specified duration. Unit hydrographs are then scaled and combined to construct a synthetic hydrograph.

The SCS studied unit hydrographs from many small watersheds and developed a simplified method of representing them by a triangular shaped hydrograph.



The hydrograph can be plotted given T_p, T_r, and Q_p. T_p is defined as 1/2 the duration of rainfall plus the log-to-peak, t_p. The log-to-peak, t_p, is roughly 0.6 of the time of concentration, t_c. Therefore,

$$T_p = 0.5\ D_r + 0/6\ t_c \qquad (6)$$

From the definition sketch we know that

$$R = \frac{Qpk\ Tp}{2} = \frac{Qpk\ Tr}{2} \qquad (7)$$

So

$$Qpk = \frac{2R}{Tp = Tr} \quad \text{(in/hr)} \qquad (8)$$

By examining a large number of hydrographs, SCS has determined that

$$Tr \approx 1.67\ Tp \qquad (9)$$

Combining equations 6-9 and converting to cfs provides an expression for Qpk in terms of runoff volume, R, basin area (mi^2), A, duration of rainfall, Dr, and time of runoff concentration, tc.

$$Qpk = \frac{484\ AR}{0.5\ Dr + 0.6\ tc} \qquad (10)$$

Although several empirical procedures are available, the SCS usually uses the following formula to calculate the time of concentration of runoff, tc,

$$tc = \left(\frac{L}{7700H}\right)^{0.38} 1.15 \qquad (11)$$

Where L is catchment length (ft.) along the main channel and H is the catchment relief (ft.)

The model used in this course used the following formula for tc:

t_c = L/0.6, hours

L = watershed lag, hours

$$= \frac{\ell^{0.8} (S = 1)^{0.7}}{1900\ y^{0.5}}$$

ℓ = length of the longest stream channel (ft.)

S = (1000/CN) - 10 , inches

y = average watershed slope in percent

Reference: Kent, K.M. 1973. A Method of Estimating Volume and Rate of Runoff in Small Watersheds. USDA, SCS-TP-149 (Revised April 1973). ca. 80 pp.

Computer Problems

RUNOFF ROUTING THROUGH A RESERVOIR

Once a design runoff hydrograph has been determined - either by unit hydrograph methods or runoff models - the hydrologist may wish to determine the effects of a reservoir on that hydrograph. Or he may have a management objective related to the reduction of flood peaks and may wish to design a reservoir to accomplish those objectives. In either case, an analytical tool is needed to relate reservoir size and outflow (spillway) characteristics to changes in the runoff hydrograph.

The routing of runoff through a reservoir generally involves an accounting of inflow volumes, outflow volumes, and changes in reservoir storage over finite increments of time. The mathematical expression of this accounting procedure is:

$$I - O = \Delta S$$

where I is inflow volume, O is outflow volume, and S is change in reservoir storage.

The inflow volume is determined from the design inflow hydrograph (e.g., the one determined by the SCS curve number model). Inflow volume is equal to the product of the inflow rate and the finite increment of time.

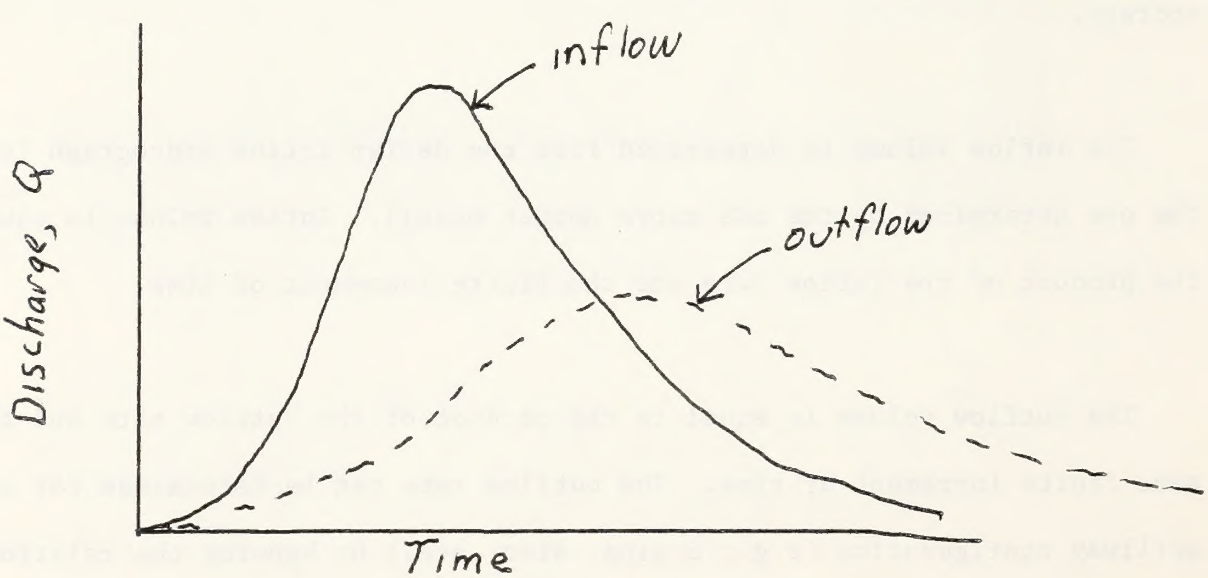
The outflow volume is equal to the product of the outflow rate and the same finite increment of time. The outflow rate can be determined for any spillway configuration (e.g., a pipe, wier, etc.) by knowing the relationship

between outflow rate and depth of water above the outflow device. This relationship is available for most spillway designs.

The change of water storage within the reservoir is simply a function of the reservoir shape (surface area) and the change in water depth over the finite increment of time.

When given (1) an inflow hydrograph, (2) a relationship between water volume and depth within the reservoir, and (3) a relationship between depth within the reservoir and outflow rate, the routing equation above can be solved. This is because we have two relationships (equations) equating reservoir depth to the two unknowns in the routing equation (outflow rate and change in reservoir volume)

The reservoir routing equation is solved easily on the computer for small time increments given user-supplied information on depth-storage and depth-outflow relationships. The effects of reservoir routing on a flood hydrograph are shown be below:

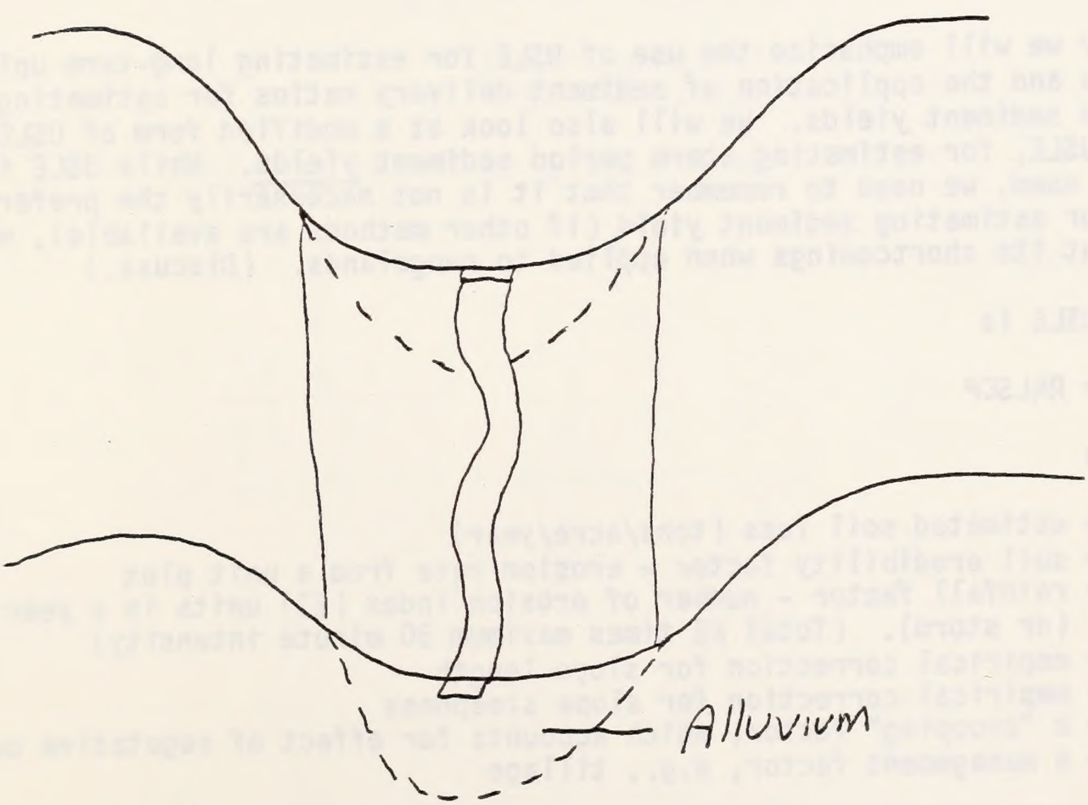


The variables which influence reductions in runoff peak and volumes include spillway type, size and elevation, and reservoir size and shape.

Erosion and Sediment Yield

It is important in a discussion of erosion and sediment yield to distinguish between the two terms and the various procedures for quantifying rates of erosion and sediment yield.

Erosion involves the detachment, entrainment, and transport of soil/geologic material from a given place - usually by forces of wind or water. Erosion is usually preceded by various weathering processes. While some detached and entrained particles are transported without interruption to the sea, most particles are redeposited and reside for varying periods of time (minutes to centuries) as depositional features. Sediment yield, at any given point, is the net of erosion minus deposition over a given period of time upstream from that point. It becomes the volume of material transported past a given point over a given period of time. (See Figure)



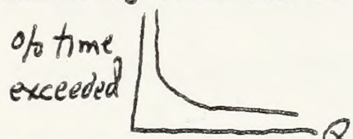
Surface erosion processes on rangelands include sheet wash (interrill) erosion, rilling, and channel erosion, including gullying. Alluvial valley fills are the most common deposition feature. Rill and interrill erosion are dominant on uplands. Channel/gully erosion is the predominant process on alluvial fills.

Upland rill-interrill erosion rates are commonly estimated using the Universal Soil for Equation (USLE). Channel erosion may be estimated using various sediment transport relationships. There are no accepted, commonly used methods for estimating gully erosion rates.

Sediment yield rates may be determined by any one of at least four general methods:

1. Reservoir surveys - assessing sediment trap efficiencies

2. Combining instream flow-duration and sediment rating curves



3. Estimating upland erosion and applying a sediment delivery ratio

4. Applying an empirical sediment yield procedure

The most commonly used sediment yield procedure is the PSIAC procedure.

Handout

Today we will emphasize the use of USLE for estimating long-term upland soil loss and the application of sediment delivery ratios for estimating long-term sediment yields. We will also look at a modified form of USLE, called MUSLE, for estimating storm period sediment yields. While USLE is commonly used, we need to remember that it is not necessarily the preferred method for estimating sediment yield (if other methods are available), nor is it without its shortcomings when applied to rangelands. (Discuss.)

The USLE is

$$A = RKLSCP$$

where

A = estimated soil loss (tons/acre/year)
K = soil erodibility factor - erosion rate from a unit plot
R = rainfall factor - number of erosion index (EI) units in a year (or storm). (Total KE times maximum 30 minute intensity)
L = empirical correction for slope length
S = empirical correction for slope steepness
C = a "cropping" factor, which accounts for effect of vegetative cover
P = a management factor, e.g., tillage

The K factor is published in soil surveys or may be obtained empirically from soil texture information. R is typically determined from two year, six hour rainfall (Figure). LS is obtained from a published chart (Figure). In the absence of better information, C is obtained from Table in Ag. Handbook 537 (Figure).

Handouts

Most sediment delivery ratios are published as relationships to watershed area.

Handouts

Considerable judgment must be applied, however, in the application of USLE for sediment yield estimates.

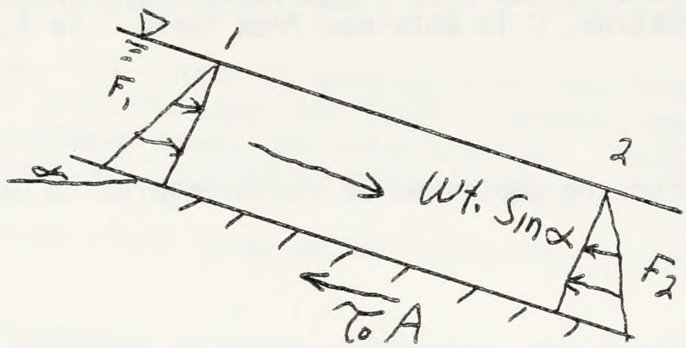
MUSLE

Foster, Meyer, and Onstad modified USLE to directly estimate storm-period sediment yield. They replaced the R-factor in USLE with a runoff energy factor.

$$Y = 11.8 \, (Q q_p)^{0.56} \, KCPSL$$

Channel Geometry Surveys and the Application of Manning's Equation

Derivation of Average Bed Shear Stress, τ_o :



$F_1 = F_2$ (hydrostatic)

$$Wt.\ \mathrm{Sin}\,\alpha = \tau_o (L * \mathrm{Perim.}) = 0$$

$$\tau_o = \frac{Wt.\ \sin\alpha}{L.P} = \frac{\gamma AL \sin\alpha}{L.P}$$

$$\tau_o = \gamma \frac{A}{P} \sin\alpha = \gamma R S_e$$

Derivation of Friction-type Flow Equations" Manning's Equation

$$\tau_o = \gamma RS = \frac{\text{drag force}}{\text{unit area}} = \rho C_D \frac{V^2}{2}$$

ρ = density of water

C_D = drag coefficient

$\frac{V^2}{2}$ = kenetic energy term from Bernouli

rearranging:

$$S_f = \frac{C_D}{R} \overbrace{\frac{\rho}{\gamma}}^{1/g} \frac{V^2}{2} = \frac{C_D}{R} \frac{V^2}{2g}$$

head loss due to friction

$$S_f = \frac{h_l}{L} = \frac{C_D}{R} \frac{V^2}{2g}$$

$$\therefore h_l = C_D \frac{L}{R} \frac{V^2}{2g}$$

Drag coef. geom term KE Term

Rearranging and
solving for Velocity, V:

$$V = \underbrace{\sqrt{2g/C_D}}_{\text{Chezy Coef}} \sqrt{R\, S_f}$$

Now, solve empirically for Chezy Coefficient in terms of the hydraulic radius, R, and a dimensionless roughness coefficient,

Studies show that

$$C = \frac{1}{n} R^{1/6}$$

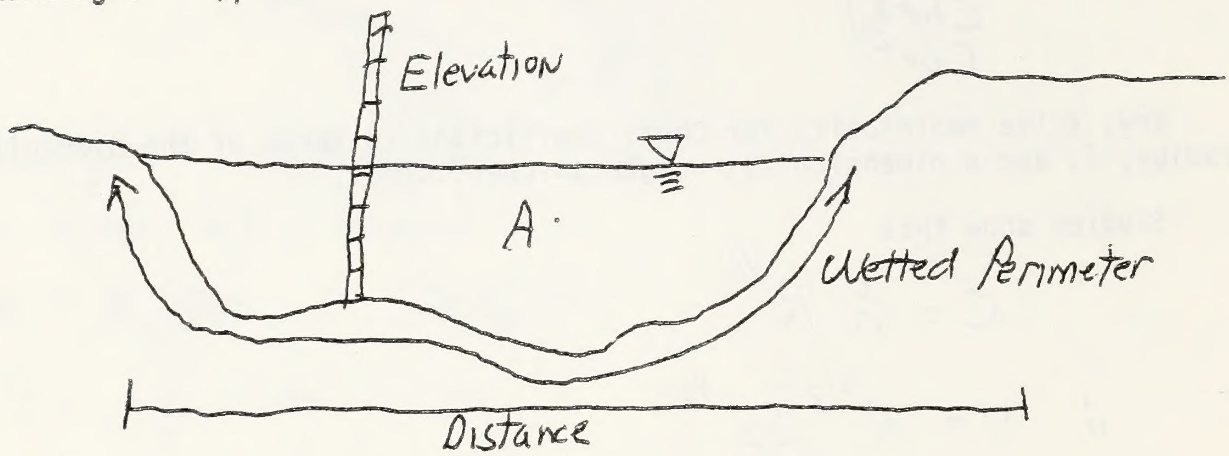
$$\therefore\ V = \frac{R^{2/3} S_f^{1/2}}{n}$$

in English Units

$$V = \frac{1.49}{n} R^{2/3} S^{1/2}$$

To solve for Manning's Equation from Channel Geometry Surveys, we need measures of

x-Section area } $A/P = R$
Wetted Perimeter
Slope
Manning's n



n: either measure flow and back-calculate, or; use table:

Handout

COMPUTER FLOOD HYDROGRAPH GENERATION EXERCISE[1/]

Background:

A Tributary to The Pussytoes Hollow watershed is 1.6 mi^2 in area, and in its virgin state contains a Ponderosa pine-grass vegetation with a cover density of 50%. The average land slope of the watershed is 30%, the average channel slope (along the largest drainage path) is 5%, along which it's 8000 ft. from the mouth to the farthest divide. The hamlet of Poison Spider, Wyoming is nearby, and its rainfall records (thought to be representative of Pussytoes Hollow) are attached in reduced form. The average annual precipitation is about 18 inches.

Using the hydrograph program:

1. A. What is the runoff depth (inches) and flood peak (ft^3/sec(from a 25 year - 6 hour storm?

   B. (Optional - for your own extra personal pleasure)

      1) What's the effect on runoff depth and flood peak of a 10% error in your estimation of CN?

      2) Ditto for a 10% error in rainfall depth.

      3. Ditto - for flood peaks only - for a 10% error in time of concentration.

2. A rehab project is then undertaken. The area is pitted, seeded, and fertilized with the aim of bringing it back into maximum possible production grazing (summer only). What's the runoff and flood peak now?

3. Construct a flood frequency curve for the watershed in its virgin state, (Problem 1). Use 6 hour storms and the NE4-4 distribution.

1/ This exercise was developed by Pete Hawkins, Utah State University, for BLM Training Course 7000-8.

RAINFALL FREQUENCY CHART
DEPTH IN INCHES

POISON SPIDER, WYOMING

DURATION	Return Period 2yr	10yr	25yr	50yr	100yr
5 min	0.35	0.70	0.80	0.88	0.94
10 min		0.80	0.93	1.00	
20 min		1.00	1.18	1.30	
30 min	0.48	1.15	1.35	1.48	1.62
45 min		1.30	1.55	1.70	
60 min	0.56	1.40	1.70	1.88	2.06
2 Hr	0.75	1.82	2.00	2.30	2.52
6 Hr	1.35	2.65	2.95	3.40	3.65

Revised 4/83 - RHH

SECTION 5

CURVE NUMBER ESTIMATION [1]

The volume and rate of runoff depends on both meteorologic and watershed characteristics, and the estimation of runoff requires an index to represent these two factors. The precipitation volume is probably the single most important meteorological characteristic in estimating the volume of runoff. The soil type, land use, and the hydrologic condition of the cover are the watershed factors that will have the most significant impact in estimating the volume of runoff. The antecedent soil moisture will also be an important determinant of runoff volume.

The SCS developed an index, which was called the runoff curve number (CN), to represent the combined hydrologic effect of soil, land use, agricultural land treatment class, hydrologic condition, and antecedent soil moisture. These factors can be assessed from soil surveys, site investigations, and land use maps; when using the SCS hydrologic methods for design the specification of the antecedent soil moisture condition is often a policy decision that suggests average watershed conditions rather than a recognition of a hydrologic condition at a particular time and place.

<u>Soil Group Classification</u>

SCS developed a soil classification system that consists of four groups which are identified by the letters A, B, C, and D. Soil characteristics that are associated with each group are as follows:

Group A: deep sand, deep loess, aggregated silts

Group B: shallow loess, sandy loam

Group C: clay loams, shallow sandy loam, soils low in organic content, and soils usually high in clay

Group D: soils that swell significantly when wet, heavy plastic clays, and certain saline soils

The SCS soil group can be identified at a site using one of three ways:

1. soil characteristics

2. county soil surveys

3. minimum infiltration rate

The soil characteristics associated with each group are listed above. County soil surveys, where they are made available by Soil Conservation Districts, give a detailed description of the soils at locations within a county; these surveys are usually the best means of identifying the soil group. Soil

1. From McCuen, "A guide to Hydrologic Analysis using SCS Methods" Prentice Hall Publishers.

analyses can be used to estimate the minimum infiltration rates, which can be used to classify the soil using the following values:

Group	Minimum Infiltration Rate (in/hr)
A	0.30 - 0.45
B	0.15 - 0.30
C	0.05 - 0.15
D	0 - 0.05

Cover Complex Classification

The SCS cover complex classification consists of three factors: land use, treatment or practice, and hydrologic condition. There are approximately fifteen different land uses that are identified in the tables for estimating curve number. Agricultural land uses are often subdivided by treatment or practices, such as contoured or straight row; this separation reflects the different hydrologic runoff potential that is associated with variation in land treatment. The hydrologic condition reflects the level of land management; it is separated with three classes: poor, fair, and good. Not all of the land uses are separated by treatment or condition.

Curve Number Estimation

Table 2, which is a compilation of the CN tables provided in NEH-4 and TR-55, show the CN values for the different land uses, treatment, and hydrologic condition; separate values are given for each soil group. For example, the CN for a wooded area with good cover and soil group B is 55; for soil group C, the CN would increase to 70. If the cover (on soil group B) is poor, then the CN will be 66.

Antecedent Soil Moisture Condition

Antecedent soil moisture is known to have a significant effect on both the volume and rate of runoff. Recognizing that it is a significant factor, SCS developed three antecedent soil moisture conditions, which were labeled I, II, and III. The soil condition for each is as follows:

Condition I: soils are dry but not to wilting point; satisfactory cultivation has taken place.

Condition II: average conditions

Condition III: heavy rainfall, or light rainfall and low temperatures have occurred within the last 5 days; saturated soil.

The following table gives seasonal rainfall limits for the three antecedent soil moisture conditions:

	Total 5-day Antecedent Rainfall (inches)	
AMC	Dormant Season	Growing Season
I	Less than 0.5	Less than 1.4
II	0.5 to 1.1	1.4 to 2.1
III	over 1.1	over 2.1

TABLE 2. Runoff Curve Numbers for Hydrologic Soil-Cover Complexes

(Antecedent Moisture Condition II, and $I_a = 0.2\ S$)

Land Use Description/Treatment/Hydrologic Condition			Hydrologic Soil Group A	B	C	D
Residential:[1/]						
Average lot size	Average % Impervious[2/]					
1/8 acre or less	65		77	85	90	92
1/4 acre	38		61	75	83	87
1/3 acre	30		57	72	81	86
1/2 acre	25		54	70	80	85
1 acre	20		51	68	79	84
Paved parking lots, roofs, driveways, etc.[3/]			98	98	98	98
Streets and roads:						
paved with curbs and storm sewers[3/]			98	98	98	98
gravel			76	85	89	91
dirt			72	82	87	89
Commercial and business areas (85% impervious)			89	92	94	95
Industrial districts (72% impervious)			81	88	91	93
Open Spaces, lawns, parks, golf courses, cemeteries,etc.						
good condition: grass cover on 75% or more of the area			39	61	74	80
fair condition: grass cover on 50% to 75% of the area			49	69	79	84
Fallow	Straight row	---	77	86	91	94
Row crops	Straight row	Poor	72	81	88	91
	Straight row	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	Contoured	Good	65	75	82	86
	Contoured & terraced	Poor	66	74	80	82
	Contoured & terraced	Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured & terraced	Poor	61	72	79	82
		Good	59	70	78	81
Close -seeded	Straight row	Poor	66	77	85	89
legumes[4/]	Straight row	Good	58	72	81	85
or	Contoured	Poor	64	75	83	85
rotation	Contoured	Good	55	69	78	83
meadow	Contoured & terraced	Poor	63	73	80	83
	Contoured & terraced	Good	51	67	76	80
Pasture		Poor	68	79	86	89
or range		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
	Contoured	Fair	25	59	75	83
	Contoured	Good	6	35	70	79
Meadow		Good	30	58	71	78
Woods or		Poor	45	66	77	83
Forest land		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads		---	59	74	82	86

[1/] Curve numbers are computed assuming the runoff from the house and driveway is directed towards the street with a minimum of roof water directed to lawns where additional infiltration could occur.

[2/] The remaining pervious areas (lawn) are considered to be in good pasture condition for these curve numbers.

[3/] In some warmer climates of the country a curve number of 95 may be used.

[4/] Close -drilled or broadcast.

Runoff Curve Numbers for Surface Treatments

Treatment	Soil Group A	B	C	D
Contour Furrowing	26	57	70	78
	47	67	81	88
Imprinting	30	58	71	78
	47	67	81	88
Pitting	34	59	72	79
	57	73	83	88
Ripping	39	61	74	80
	68	79	86	89

Upper values are for 100% cover. Lower values are for bare soil conditions

Source: Summer, R. N. 1983(?). Use of Land Surface Mechanical Treatments to Control Erosion from Small Area Disturbances on Mined Lands. Soil Cons. Soc. America Spec. Pub. (manuscript: in press)

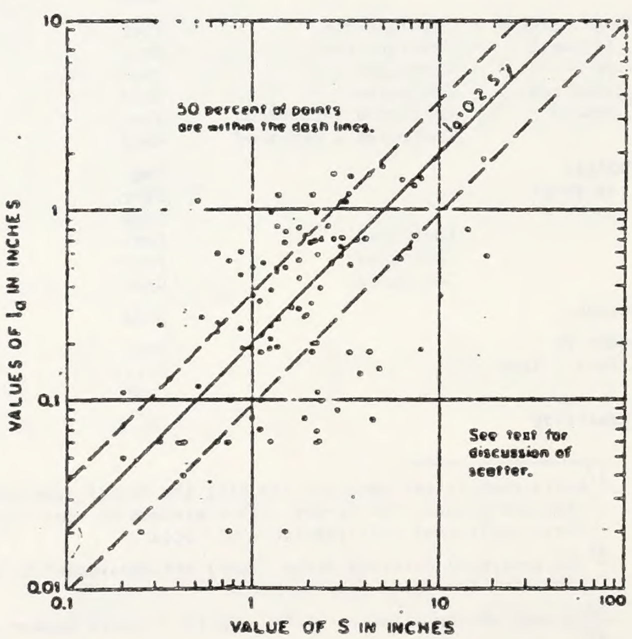


Figure 10.2.--Relationship of I_a and S. Plotted points are derived from experimental watershed data.

Table 11-10. Values of a and b for CN = a - bX where X is percent cover for various vegetation types and soil groups. (From Branson, et.al. Rangeland Hydrology)

Vegetation type	Soil group	a	b	Notes
Juniper-grass	C	88	0.32	1
	B	82	0.42	1
Sage-grass	C	86.5	0.46	1
	B	73.5	0.415	1
Herbaceous	D	95	0.115	1
	C	90	0.19	1
	B	84	0.25	1
Oak-aspen	C	79	0.44	1
	B	74	0.51	1
Desert brush	D	93	0.06	2 3
	C	80	0.06	2 3
	B	84	0.06	2 3
Ponderosa pine	C	83	0.14	2 4
	B	73	0.31	2 4
Pasture or rangeland	A	77	0.56	3
	A	63	0.28	6
	B	83	0.28	
	C	89	0.18	
	D	91	0.13	5
Annual grass	A	75	0.44	3
	A	60	0.13	6
	B	83	0.26	
	C	89	0.18	
	D	91	0.13	7
Forests (P=25 inches)	A	50.5	0.286	
	B	71.5	0.229	
	C	81.5	0.229	
	D	87	0.21	7
Roads	A	73	0	
	B	83	0	
	C	88.5	0	
	D	90.5	0	
Bare rock		96	0	8
Water surfaces		100	0	

All above curve numbers for AMC II, and $I_a = 0.2S$, Cover without rocks. [1]From Enderlin and Markowitz (1962). [2]From Simanton, Renard, and Sutter (1973). [3]For $X \leq 50\%$. [4]For $10\% < X < 80\%$. Nonlinear relationship to Y = 83 and Y = 73, respectively at X = 0. [5]From NEH-4 (in table form), reduced and converted to above coefficients. [6]For $X > 50\%$. Note similarity between annual grass and rangeland coefficients except for Soil Group "A". [7]From unpublished tables from U.S. Forest Service personnel (personal communication). [8]Assumes Initial Abstraction = 0.08 inch.

In design, the antecedent soil moisture condition is often a policy decision rather than a statement of actual soil conditions at the site during development.

The CN values obtained from Table 2 are for soil moisture condition II. If either soil condition I or III is to be used, the CN can be adjusted using the following table:

CN for Condition II	Corresponding CN for Condition 1	III
100	100	100
95	87	99
90	78	98
85	70	97
80	63	94
75	57	91
70	51	87
65	45	83
60	40	79
55	35	75
50	31	70
45	27	65
40	23	60
35	19	55
30	15	50
25	12	45
20	9	39
15	7	33
10	4	26
5	2	17
0	0	0

The following table gives seasonal rainfall limits for the three antecedent soil moisture conditions:

AMC	Total 5-day Antecedent Rainfall (inches) Dormant Season	Growing Season
I	Less than 0.5	Less than 1.4
II	0.5 to 1.1	1.4 to 2.1
III	over 1.1	over 2.1

From McCuen, R.H. A Guide to Hydrologic Analysis Using SCS Methods. Prentice-Hall, 1982, 145 pp.

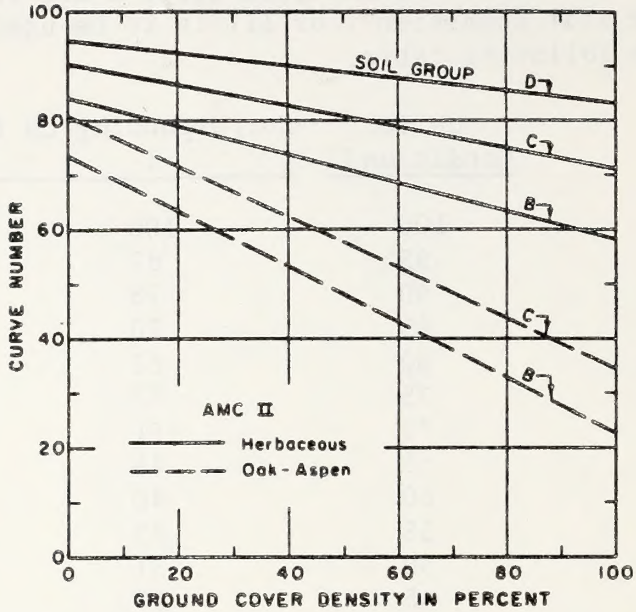


Figure 9.5.--Graph for estimating runoff curve numbers of forest-range complexes in western United States: herbaceous and oak-aspen complexes.

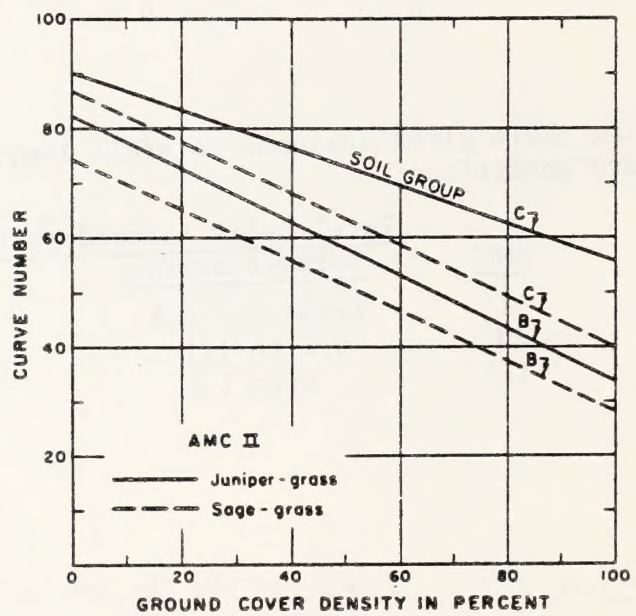


Figure 9.6.--Graph for estimating runoff curve numbers of forest-range complexes in western United States: juniper-grass and sage-grass complexes.

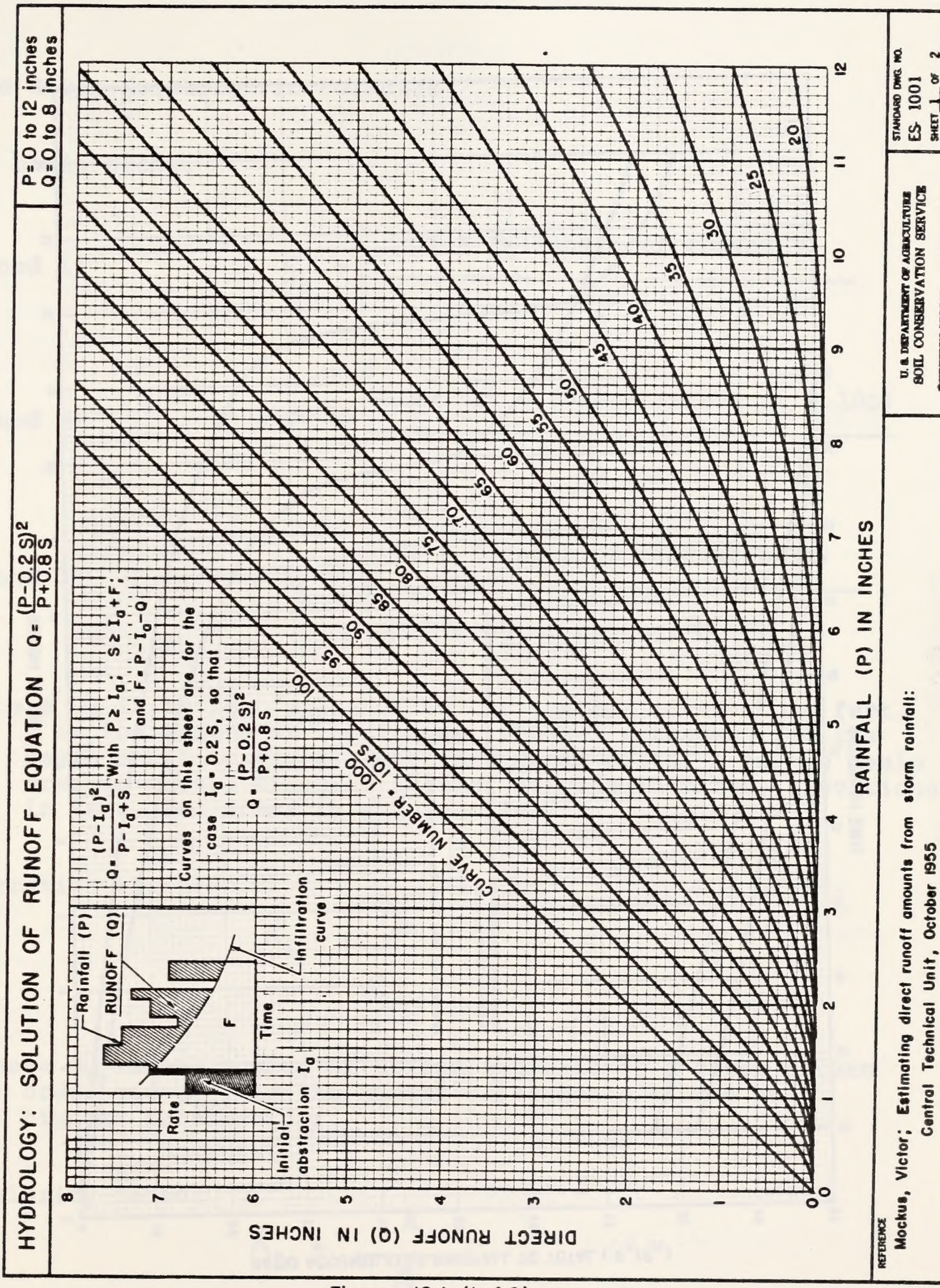


Figure - 10.1 (1 of 2)

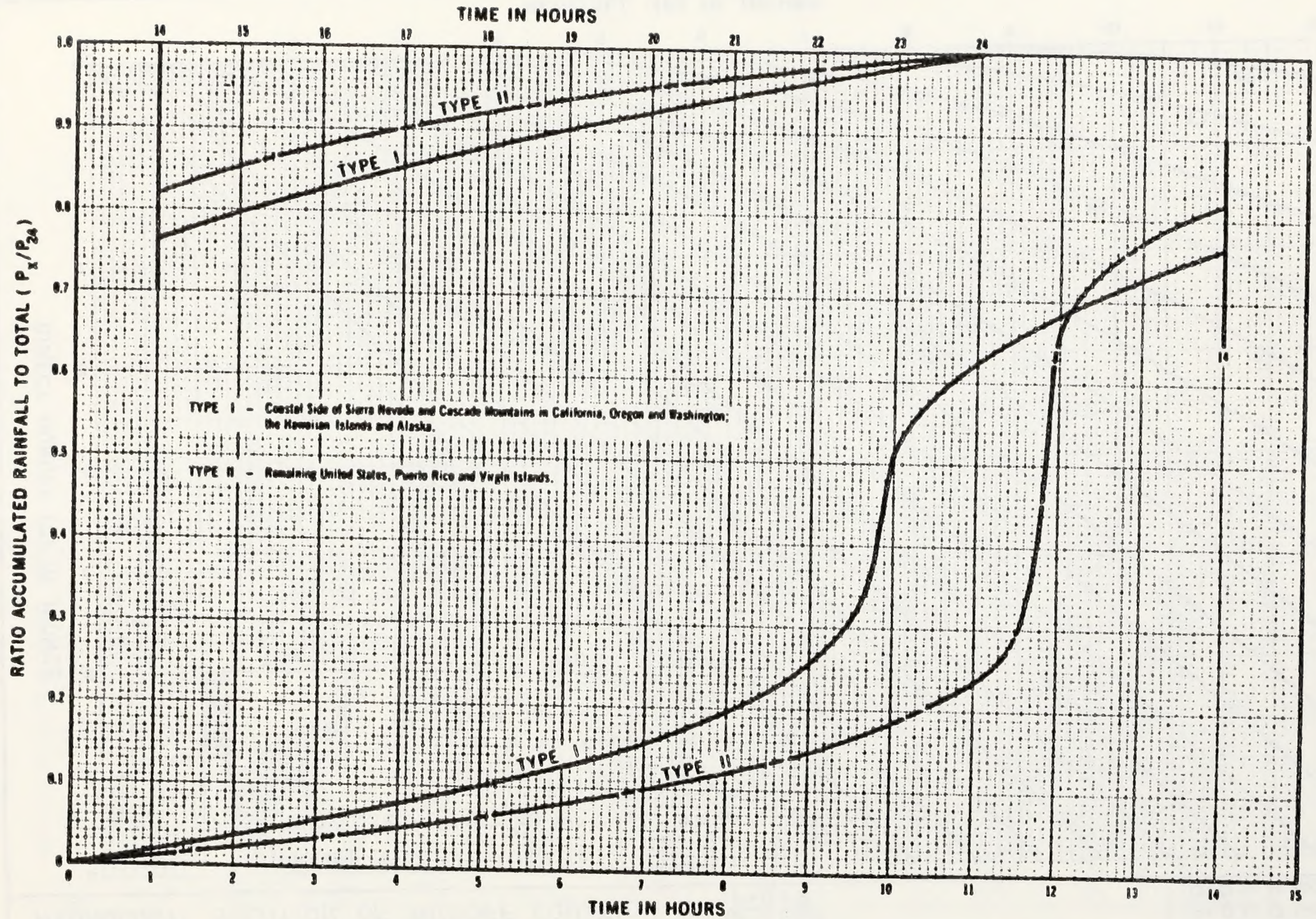


Figure 2. Twenty-four hour rainfall distributions (SCS).

Drainage Basin Morphometric Formulas

Mean basin slope:

(Method 1) $$S_b = \frac{CI * \sum(\text{length of contours})}{A}$$

(Method 2) $$S_b = \frac{(\text{elev. at } 0.85L) - (\text{elev. at } 0.10L)}{0.75L}$$

(Method 3) $$S_b = \frac{CI * (\text{length of contour belt})}{(\text{area of contour belt})}$$

where S_b is in feet/mile, CI is the contour interval in feet, L is the length of the longest channel extended from the basin mouth to the drainage divide in miles, A is the basin area in square miles, all other lengths in miles, elevations in feet, and areas in square miles.

Bifurcation ratio:

$$R_b = \frac{N_u}{N_{u+1}}$$

where N_u is the number of stream segments of a given stream order and N_{u+1} is the number of segments of the next highest stream order.

Circularity ratio:

$$R_c = \frac{A}{A_c}$$

where A is the basin area and A_c is the area of a circle having the same perimeter as the basin.

NATIONAL ENGINEERING HANDBOOK

SECTION 4

HYDROLOGY

CHAPTER 11. ESTIMATION OF DIRECT RUNOFF FROM SNOWMELT

This chapter gives methods for estimating snowmelt runoff volumes for flood damage evaluations. Methods of snowmelt forecasting, for irrigation and similar purposes, are described in the Snow Survey Handbook of the Service.

Details of the thermodynamics of snowmelt are omitted from this chapter because of their limited value in the methods presented here. Some standard references are:

Clyde, George D. - Snow-melting characteristics. Technical Bulletin 231, August 1931. Utah Agricultural Experiment Station, Logan, Utah.

Light, Phillip - Analysis of high rates of snowmelting. Pages 195-205, Transactions of the American Geophysical Union, 1941.

Wilson, W. T. An outline of the thermodynamics of snowmelt. Pages 182-195, Transactions of the American Geophysical Union, 1941.

Significance of Snowmelt Floods

Bankfull capacities in csm are normally greater for small watersheds than for large ones. Since snowmelt rates are relatively low in csm there may be flooding on large watersheds when streams on small watersheds are flowing less than bankfull.

The hydrologist acquainted with an area will know the relative importance of snowmelt as a source of flooding in that are. In doubtful cases the data normally gathered by interview for an historical flood series will usually define the character of flood flows. In other instances, the runoff records will show how important snowmelt flooding is. It is seldom necessary to make detailed hydrologic investigations into the matter.

Methods of Estimation

Regional analysis

This method is one of the most useful for snowmelt floods. See Chapter 2 for details of the method.

Degree-day method, ungaged watersheds

This method is widely used because of its adaptability to usual data conditions. Similar methods going into more detail are available but seldom applicable because of lack of required data.

The degree-day method uses the equation:

$$M = K\,D \tag{11-1}$$

where M = the watershed snowmelt in inches per day.

K = a constant that varies with watershed and climatic conditions.

D = the number of degree-days for a given day.

A degree-day is a day with an average temperature one degree above 32° F. Maximum and minimum temperatures, as found in "Climatological Data," are averaged to get the daily average temperature. A day with an average of 40° F. gives eight degree-days; with an average of 51° F., nineteen degree days. The general form of the method is given below. A working arrangement of the data is shown on table 11-1. In most cases the table can be condensed. The steps in the method are:

1. Using precipitation stations or snow survey data, show either (a) the total available water equivalent at the beginning of the melt season (table 11-1) or (b) the precipitation and the water equivalent by days (table 11-2). The first procedure is used where there is generally only one melt period per year; the second, where melt periods occur intermittently through the winter and spring. Water equivalent is the depth of water, in inches, that results from melting a given depth of snow, and it is dependent on both depth and density of snow. Snow surveys give field determinations of water equivalents. Where such surveys are not made, it is customary to use one-tenth of the snow depth as the depth of water equivalent.

2. For temperature stations in the watershed, tabulate average temperatures for the melt periods. (Note: maximum and minimum values as given in "Climatological Data" can be averaged mentally to avoid tabulation of averages below 33° F.)

Table 11-1. Estimation of snowmelt by degree-day method. One melt period

Dates	Watershed average temperature °F. 1/	Degree-days	Estimated snowmelt 2/	Total available water equivalent
			Inches	Inches
April 5	32	0	0	4.50
6	35	3	.18	4.32
7	34	2	.12	4.20
8	36	4	.24	3.96
9	48	16	.96	3.00
10	43	11	.66	2.34
etc.	etc.	etc.	etc.	etc.

1/ Average of two stations; adjusted for altitude.

2/ Using K = 0.06 in equation 11-1.

Table 11-2. Estimation of snowmelt by degree-day method. Intermittent melt period.

Dates	Precipitation	Water equivalent 1/	Degree-days	Snowmelt Potential 2/	Snowmelt Estimated	Remaining water equivalent
	Inches	Inches		Inches	Inches	Inches
Nov 3	0.85	0.08				0.08
Nov 4-18						.08
Nov 19			5	0.30	0.08	0
Nov 20-29						0
Nov 30	3.80	.38				.38
Dec 1-24						.38
Dec 25	4.15	.42				.80
Dec 26-Jan 18						.80
Jan 19	.52	.05				.85
Jan 20-Feb 2						.85
Feb 3-20	6.92	.69				1.54
Feb 21-Mar 14						1.54
Mar 15	14.24	1.42				2.96
Mar 16-28						2.96
Mar 29			3	.18	.18	2.78
Mar 30			11	.66	.66	2.12
Mar 31			22	1.32	1.32	.80
Apr 1-9						.80
Apr 10			7	.42	.42	.38
Apr 11			32	1.92	.38	0

1/ One-tenth of snow depth.
2/ Using K = 0.06 in equation 11-1.

3. Adjust the average temperatures to the average watershed elevation, using the method given below in <u>Adjustment of temperatures for altitude</u>. This step is omitted when elevation data are crude or otherwise unreliable.

4. Compute the watershed average daily temperatures by averaging the station averages (adjusted for altitude, if desirable).

5. Subtract 32° F. from each watershed average daily temperature to get the degree-days per day.

6. Use equation 11-1 to get an estimate of the potential <u>snowmelt</u> for each day. See <u>K factors</u> below for selection of <u>K</u>.

7. Where the daily potential is not greater than the water equivalent remaining on the watershed, it is shown as an estimate of snowmelt.

Once the estimates of snowmelt are obtained, they are used to obtain hydrographs as described in Chapter 16.

Some hydrologists suggest that the effects of infiltration be subtracted from the estimated snowmelt. However, the K factors as generally developed already include the effects of infiltration. The effects of measures such as contour furrows are obtained as described in Chapter 12. The effects of reservoirs, levees, etc. are obtained as usual.

Refinements in the degree-day method are best made by first improving the accuracy of determinations of snow depth and areal distribution on the watershed. When these are known within small limits of error, then water equivalents should be refined, since the 1/10 ratio is a rough approximation. Refinements in K factors should come last.

<u>Degree-day method, gaged watershed</u>
The degree-day method has a very limited use, if any at all, for flood evaluations on gaged watersheds. When gaging station data are available, those data should be used to estimate flood peaks and volumes on other portions of the watershed.

<u>Adjustment of temperatures for altitude</u>
In general, air temperatures decrease about 3° to 5° for every 1,000 feet of rise in altitude. Other factors influence this "lapse rate," so that refinements are not justified, and an average decrease of 4° F. per 1,000 feet rise should be used.

Example 11-1—A watershed with an average elevation of 4,600 feet had temperature station readings of 38° F. at a 5600-foot elevation, and 48° F. at a 3000-foot elevation. The average temperature for the watershed is then:

$$(38) - \frac{4}{1000}(4600 - 5600) = 42.0$$

$$(48) - \frac{4}{1000}(4600 - 3000) = 41.6$$

Sum: 83.6

Average: 41.8

Round off to: 42

While further refinements, such as weighting, can be made, they are seldom justified.

K factors

The constant K in equation 11-1 is known to vary not only from watershed to watershed, but also from day to day on a given watershed. It is seldom possible to do more than make a broad estimate of K. An average value of 0.06 can be used. The following table may be of assistance in special cases:

Table 11-3. K factors

Condition	K
Extremely low runoff potential	0.02
Average heavily-forested areas; north-facing slopes of open country	.04 - .06 1/
Average	.06
South-facing slopes of forested areas; average open country	.06 - .08 1/
Extremely high runoff potential	.30

1/ Recommended by A. L. Sharp.

Concordant flow method
The method of Chapter 2 can be simplified to estimate both peaks and volumes of snowmelt runoff, when at least one streamflow record is available. The method is very similar to the Regional analysis method mentioned above and in Chapter 2.

The volume of snowmelt for an ungaged subwatershed is the same as that for the gaged watershed, assuming equal coverage of snow over both areas. Where it is possible to estimate the amounts or degrees of snow coverage, the snowmelt volumes in inches may be taken as directly proportional to snow depth or degree of coverage. For example, if there is a 3.2" snowmelt runoff from a gaged watershed of 82 square miles with 76 percent of the watershed having snow cover, then a subwatershed of 12 square miles and 100 percent snow cover will have an estimated runoff of:

$$3.2 \frac{(100)}{(76)} = 4.2 \text{ inches.}$$

Note that area in square miles is not used in the computation unless acre-feet are needed. If instead of the percents the gaged watershed is known to have an average of 16.2 inches of snow-depth and the ungaged subwatershed 20.4 inches, then the runoff for the subwatershed is:

$$3.2 \frac{(20.4)}{(16.2)} = 4.0 \text{ inches.}$$

Other factors can be brought in, but here again refinement is not justified.

Peaks of snowmelt runoff can be obtained as described in Chapter 16.

Other methods
Where intensive study has been or can be made of a watershed, more detailed and more accurate methods of estimating snowmelt runoff can be used.

IN: Proceedings of the Workshop on Estimating Erosion and Sediment Yield on Rangelands TUCSON, AZ May 7-8, 1981 ARM-W-26, 1982.

SEDIMENT YIELD FROM SMALL SEMIARID RANGELAND WATERSHEDS

K. G. Renard and J. J. Stone[1]

INTRODUCTION

Sediment yield, the quantity of sediment moving past a cross-section of a channel in a specified time interval, is sometimes mistakenly assumed to be synonomous with erosion. Material removed from a slope as rill and interrill erosion may be deposited at the toe of a slope, on a flood plain, or at other points within the watershed where the sediment load exceeds the transport capacity of the runoff. Within a channel, material eroded not only from the landslope, but also from the channel bed and banks and from gullies and headcuts, can be a significant part of the sediment transported past a point on the stream. The path that a soil particle takes in moving to a point of lower potential energy is complicated, and the process is often stepwise in time.

Assuming that governing equations for such movements are known, these complexities make physically based equations describing the movement of sediment difficult to use. Thus, more simplified empirical equations are often used. Recent developments in watershed modeling, however, include erosion/sediment transport routines with detailed hydrologic models. These new modeling techniques promise to reflect the effects of different land use and the effects of the variations from year to year resulting from climatic differences. They do, of course, require much more computer time, have different data requirements, and are more expensive to use than the simple empirical models.

Methods for estimating erosion and sediment yield from rangelands are based primarily upon the principles developed in parts of the United States where cultivated agricultural activities are prevalent. Techniques incorporating disturbance of the soil by tillage are not generally applicable to rangelands, so the erosion-estimating techniques must be adjusted to reflect these land use differences for rangelands. Typical problems unique to rangelands are those associated with the different soils (the genesis of western range soils are different from those in humid areas); the existence of erosion pavements (which provide protection from raindrop impact and decrease the shear of water moving over the land); grazing and trampling by animals; and with channel erosion processes which are very important on rangelands.

Renard (1980) detailed seven different methods for estimating sediment yield. Each has different data requirements, vary in complexity, and produce different results. The choice of method depends upon the objective of the investigation. In this further investigation, some sediment yield formulae are

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tested with sediment yield data from nine small watersheds in the Walnut Gulch Experimental Watershed near Tombstone, Arizona.

METHODS TESTED

Pacific Southwest Interagency Committee Method (PSIAC)

The method developed by the Water Management Committee of the PSIAC (1968) was intended for broad planning rather than for specific project formulation where more intensive investigations are required. Although this method was intended for use in areas larger than 10 mi^2, we tested it here on small watersheds to demonstrate a method that might be readily used to estimate sediment yield within a land resource area (Austin, 1965). Testing the method improves the confidence of the user in selecting parameter values that reproduce observed data.

The method requires using nine factors to determine the sediment yield classification for a watershed. The factors are (A) geology, (B) soils, (C) climate, (D) runoff, (E) topography, (F) ground cover, (G) land use, (H) upland erosion, and (I) channel erosion/sediment transport. Each factor is assigned a numerical value from a rating chart (PSIAC, 1968) which is too long to reproduce here. Descriptive terms for three sediment yield levels (high, moderate, low) for each factor are used to select the numerical value. Summing the rating chart values for the nine factors defines a sediment yield rating classification, which in turn can be converted to the average annual sediment yield using Table 1.

TABLE 1.--Sediment yield classification

Rating	Classification	Annual sediment yield ac-ft/mi^2
> 100	1	> 3.0
75 to 100	2	1.0 to 3.0
50 to 75	3	0.5 to 1.0
25 to 50	4	0.2 to 0.5
0 to 25	5	< 0.2

Numerical values for each of the nine factors range from 25 to minus 10. Although only three levels are suggested for general use in the rating chart, a footnote states that, if experience so dictates, interpolation between the three sediment yield levels may be made. Such interpolation was used in this study.

To assist in interpolation between the classifications of Table 1, The data in Table 1 were converted to equation form. Although such precision was not intended for the original method, we felt that such a scheme could provide additional insight into the ability of the technique to reflect differences in the observed data. The equation is:

$$Y = 0.0816e^{0.0353X} \tag{1}$$

where Y = annual sediment yield (ac-ft/mi^2)
e = natural logarithm
X = PSIAC rating factor

Dendy/Bolton Method

Dendy and Bolton (1976) derived sediment yield equations having widespread applicability because they used data from over 800 reservoirs throughout the United States to obtain measured sediment yield values. They segregated the data into areas where runoff was either less than or greater than 2 in/yr.

In areas where runoff is less than 2 in, they derived the equation:

$$S = 1280\ Q^{0.46}(1.43 - 0.26 \log A) \tag{2}$$

where S = sediment yield (t/mi^2/yr)
Q = annual runoff (in)
A = watershed area (mi^2).

Because of widely varying local factors, the authors may not have intended for this equation to be used for a specific location. However, the equation does express a rational relationship for sediment yield that seems realistic for conditions encountered in the Southwest.

To estimate the average annual runoff for a watershed, the relationship developed by Renard (1977) for the Walnut Gulch Experimental Watershed was used:

$$Q = 0.4501\ A^{-0.1449} \tag{3}$$

where the terms are as defined above. Substituting Eq. 3 into Eq. 2 gives

$$S = 887\ A^{-.0667}\ (1.43 - 0.26 \log A) \tag{4}$$

To convert the annual sediment yield to ac-ft/mi^2/yr, the sediment deposited was assumed to weighed 80 lbs/ft^3.

Flaxman Method

Flaxman (1972) developed a regression equation for reservoir design on rangeland watersheds in the western United States relating sediment yield to four parameters. His expression is

$$\begin{aligned} \log (Y + 100) &= 6.21301 - 2.19113 \log (X_1 + 100) \\ &+ 0.06034 \log (X_2 + 100) - 0.01644 \log (X_3 + 100) \\ &+ 0.04250 \log (X_4 + 100) \end{aligned} \tag{5}$$

where Y = antilog of [log (Y + 100)] - 100
Y = average annual sediment yield (ac-ft/mi^2/yr)

X_1 = ratio of average annual precipitation (in) to average annual temperature

X_2 = average watershed slope (%)

X_3 = soil particles greater than 1.0 mm (%)

X_4 = soil aggregation index

The parameters express climate and vegetative growth (X_1), topography (X_2) and soil properties (X_3 and X_4). The equation explained about 91% of the variance in average annual sediment yield from 27 watersheds ranging in size from 12 to 54 mi^2 in 10 western states.

Flaxman (1974) modified his original sediment yield prediction equation by adding an additional term to reflect the 50 percent chance peak discharge in csm (cubic ft/sec/mi^2). The revised equation included converting the dependent variable sediment yield from acre-ft in the original equation to ton/mi^2. The equation is thus given as

$$\begin{aligned} \log(Y + 100) &= 524.37321 - 270.65625 \log(X_1 + 100) \\ &+ 6.41730 \log(X_2 + 100) - 1.70177 \log(X_3 + 100) \\ &+ 4.03317 \log(X_4 + 100) + 0.99248 \log(X_5 + 100) \end{aligned} \tag{6}$$

where Y = sediment yield in ton/mi^2 yr,

X_5 = the 50 percent chance peak discharge, csm and

X, X_2, X_3, and X_4 are the same as defined in eq (5).

Renard Method

A method for estimating sediment yield was developed by Renard (1972) and Renard and Laursen (1975). This method uses (a) a stochastic runoff model (Diskin and Lane, 1972) which generates hydrographs for semiarid watersheds in the southwestern United States, and (b) a deterministic sediment tansport relationship (Laursen, 1958). Sediment yield is then computed by simulating individual hydrographs and computing the sediment transport for the simulated hydraulic conditions. Annual runoff and sediment yield is the sum of the yield of individual runoff events. Thus, sediment yield is a function of runoff volume, hydrograph peak, Manning's roughness, slope, hydraulic radius, and the size distribution of the sediment in the streambed. The method was applied and calibrated with sample data for several of the larger watersheds on Walnut Gulch in southeastern Arizona. With the model, a simplified relationship was developed which relates the annual sediment yield to watershed drainage area in the form

$$Y = 0.001846\, A_a^{-.1187} \tag{7}$$

where Y = average annual sediment yield in ac-ft/ac/yr

A_a = drainage area in acres.

Thus, because of transmission losses (abstractions from runoff by the alluvial channels) in the watershed, water yield decreases with increasing drainage area (drainage density), and this same trend is reflected in the sediment yield relationship. Conversions are required to produce the units comparable to the other methods.

Additional improvements might be made with the method if, rather than using the general relationship shown in eq. (7), actual annual runoff volume were used as input to the stochastic simulation routine along with actual bed material size distributions in the channels of the watersheds used for the testing.

MODIFIED UNIVERSAL SOIL LOSS EQUATION (MUSLE)

Williams and Berndt (1977a) have recognized that the erosion estimates of the USLE can be modified to reflect the transport of sediment in runoff and thereby, extend the use of this technique to larger areas. The Modified Universal Soil Loss Equation is given as

$$Y = 11.8\ (Vq_p)^{0.56}(K)(C)(P)(LS) \qquad (8)$$

where Y = sediment yield from the basin in Mg
V = the surface runoff volume for the basin in m^3
q_p = the peak flow rate for the basin in m^3/s
K = soil erodibility factor
C = cover and management factor
P = the erosion control practice factor
LS = slope length and steepness factor

Values of K, C, P, and LS may be input for each subbasin if the area is large enough to require spatial variability quantification.

To provide the peak flow and runoff volume estimates required by MUSLE, a hydrologic model was used called SWRRB (Williams and Nicks, 1980). The acronym stands for a "Simulator for Water Resources in Rural Basins."

The major processes included in the model are surface runoff, percolation, return flow, reservoir storage, and sedimentation. Surface runoff is computed in the model from daily rainfall values using the SCS (1972) curve number technique. Basically, SWRRB uses the CREAMS (Knisel, 1980) daily rainfall hydrology option modified for application to large, complex rural basins. The major changes involved are (a) adding a return flow component, (b) expanding the model to allow simultaneous computations on several subbasins, (c) adding a reservoir storage component to assist in evaluating the effects of farm ponds on water yield, (d) adding a weather generating model to provide for longer term simulations, and (e) using a better method to predict peak runoff rate. Although computations for predicting water and sediment yields proceed simultaneously, the hydrologic model provides the necessary inputs for MUSLE to compute sediment yield on a daily basis. Details of the model structure and method of computation are not included here because of space limitations.

WATERSHEDS CONSIDERED

The Walnut Gulch Experimental Watershed is a 58 mi^2 (150 km^2) drainage in southeastern Arizona operated by the Science and Education Administration of USDA to evaluate the effect of land use and conservation practices on water and

sediment yield of arid and semiarid rangelands. The watershed, in the Southeastern Arizona Basin and Range Land Resource Area (Austin, 1965), is typical of the intermountain alluvial areas of the Southwest. Elevations range from 4200 to 6000 ft above mean sea level. Cover is a mixture of brush and grasses with vegetation basal areas less than 10%. Soils are typically calcareous with large amounts of gravel and cobbles. A gravel pavement can develop as the land surface erodes, and in some areas it represents nearly a 100% cover.

Precipitation in the area, which averages about 14 in/yr, is dominated by summer rainfall (about two-thirds of the annual) consisting of high-intensity, short-duration thunderstorms of limited areal extent. Winter storms are generally of greater areal extent and of low intensity, so that runoff is uncommon. The summer air-mass thunderstorms result in high peak flows that generally carry high sediment loads.

Within the watershed, a number of small earthen dams (stock ponds) provide water for the grazing animals. Topographic surveys of the pond storage area have been made, periodically, to determine sediment accumulations. The nine ponds for which such information was available are shown in Table 2 along with data on the characteristics of the watershed area. The ponds generally have enough storage space so that discharge through the emergency spillway is infrequent. Pond 223 spilled more often than the others.

TABLE 2.--Characteristics of stock tanks at Walnut Gulch and of the contributing watersheds

Tank number	Drainage area mi^2	Record length	Soil association[1/]	Vegetation	Measured annual sediment accumulation $ac\text{-}ft/mi^2$
201[2/]	0.170	1960-70 1971-79	Rillito-Karro	Brush Grass	0.49 0.13
207	0.428	1962-77	Rillito-Cave-Tortugas	Brush	0.11
208	0.356	1973-77	Hathaway-Bernardino	Grass	0.13
212	1.316	1964-77	Cave-Rillito-Laveen, and Tortugas	Brush	0.11
213	0.616	1962-79	Graham-House Mountain	Brush/Grass	0.09
214	0.581	1957-77	Hathaway-Bernardino	Grass	0.37
215	0.136	1966-77	Hathaway-Nickel	Brush	0.70
216	0.325	1962-77	Hathaway-Bernardino	Grass	0.51
223	0.169	1962-77	Rillito-Laveen	Brush	0.30

1/ From Gelderman (1970).

2/ The tank drainage was root plowed and reseeded in 1971.

RESULTS AND DISCUSSION

Tables 3, 4, and 5 summarize the parameter values used in the PSIAC, Flaxman, and SWRRB/MUSLE methods, respectively. The Dendy/Bolton and Renard methods (Table 6) are simple one-parameter equations and, as such, are by far the easiest to use.

Table 3.--Summary of the factor values used to estimate sediment yield with the Pacific Southwest Interagency Committee method (Renard, 1980)

Tank number	Factor values[1/] A	B	C	D	E	F	G	H	I	Total	Computed annual sediment yield ac-ft/mi²
201 B	5[2/]	5	8	2	1	-5	0	10	10	36	0.29
201 G	5	5	8	1	1	0	-10	5	10	25	0.19
207	2	2	8	2	8	-8	- 5	10	5	24	0.18
208	5	3	8	2	1	-5	2	5	0	21	0.16
212	3	5	8	1	1	0	0	10	10	38	0.30
213	2	2	8	2	5	-5	0	5	5	24	0.18
214	5	5	8	2	2	0	2	5	15	44	0.38
215	5	3	8	2	1	-2	0	15	15	47	0.42
216	5	5	8	1	2	0	0	10	5	36	0.28
223	5	2	8	2	0	-5	-5	10	20	37	0.29

1/ The factors are defined on p. 2 of the text.

2/ Some interpolation between the three yield levels defined in the manual was used.

Table 4.--Prediction of sediment yield from watersheds at Walnut Gulch using Flaxman methods (eq. 5 and 6)

Tank number	Factor values[1/] X_1[2/]	X_2	X_3	X_4	X_5	Annual sediment yield ac-ft/mi² Y (eq. 5)	Y (eq. 6)
201	0.192	5.3	72	0	226	-0.180	0.16
207	0.206	6.9	55	0	117	0.049	0.12
208	0.179	8.6	47	0	115	0.313	0.17
212	0.206	5.8	41	0	94	0.142	0.12
213	0.206	11.0	46	0	77	0.375	0.15
214	0.216	8.6	52	0	188	0.154	0.21
215	0.216	8.7	44	0	274	0.249	0.32
216	0.216	12.0	52	0	152	0.341	0.23
223	0.206	9.4	65	0	289	0.085	0.28

1/ Factor values are defined on p. 5 for use in Eq. 5 and 6.

2/ Average temperature at Tombstone is 63.1°F. Some adjustment was made based on elevation differences between the Tombstone weather station and the pond (3° F increase per 1000 ft elevation decrease).

Table 5.--Summary of the parameter values used in SWRRB/MUSLE for the Walnut Gulch watersheds

Tank number	T.C.[1/]	Root zone depth	CN_I[2/]	K[3/]	LS[4/]	C[5/]
	(hr)	(in)				
201	.350	15.98	88.13	0.2	0.90	.08/.015
207	.421	15.98	87.19	0.1	0.98	.026
208	.407	20.08	87.45	0.234	0.99	.033
212	.528	15.98	83.97	0.399	0.74	.026
213	.454	20.94	86.51	0.455	2.89	.026
214	.449	20.08	86.63	0.1	1.63	.040
215	.335	20.08	88.25	0.234	1.33	.027
216	.339	20.08	87.57	0.234	1.94	.030
223	.350	15.98	88.13	0.1	1.83	.040

[1/] T.C. = time of concentration. T.C. = $.5A^{.2}$ where A = area in mi^2.

[2/] CN_I = from regression. CN_I = 88.75 - .00568A where A = area in acres.

[3/] K = soil erodibility factors from the USLE nomograph (Wischmeier and Smith, 1978).

[4/] LS = measured from topographic maps using Williams and Berndt (1977b) method.

[5/] C = USLE cover/management factor from field measurements; erosion pavement was included in this factor.

In developing the estimates of sediment yield with the Flaxman (1974) method given in eq. (6), the 50 percent chance peak flow was determined by taking the maximum annual runoff volume recorded for each stock pond for which data were available. The 50 percent chance volume was read from the annual flood series using a log-nornal probability distribution. The value was then converted to CSM using the volume/peak flow equation given in the SCS NEH-4 (1972) as follows:

$$X_5 = q_p \frac{640}{A_a} = \frac{484\ AQ}{D/2 + 0.6\ T_c} \left(\frac{640}{A_a}\right) \tag{9}$$

where: q_p = peak discharge,
A = drainage area (mi^2),
A_a = drainage area (acres),
Q = two year frequency runoff volume (in),
D = storm duration (assumed = 1 hr), and
T_c = time of concentration (hr).

Although the data are not shown, an independent method was also used to estimate parameter X_5 using NOAA Atlas II estimates of the 2-yr frequency 1-hr precipitation depth with an estimate of the watershed curve number and the widely used curve number equation of SCS:

$$Q = \frac{(P-0.2S)^2}{P + 0.8S} \qquad (10)$$

where: P = 2-yr frequency 1-hr duration precipitation (in),
S = potential maximum watershed retention (in),

$$S = \frac{1000}{CN} - 10$$

Estimates of curve numbers (CN's) for the watersheds involved were the same values used in the SWRRB/MUSLE method. The correlation between observed and predicted, using NOAA Atlas II precipitation estimates, was (r^2 = 0.077) poorer than that obtained with the log-normal frequency distribution for observed data. It is, however, the method recommended by Flaxman (1974) when data for a specific watershed are not available. The improvement of the estimated sediment yield is dramatic with the addition of the additional parameter. Estimated sediment yield in the absence of observed runoff data tended to overpredict at low sediment yields and underpredict at higher yields, as was observed for all methods.

As can be seen from the summary, Table 6, the PSIAC method generally agreed most closely with the measured data. The PSIAC and MUSLE methods enabled prediction of the change in sediment yield with changes in cover after the treatment of tank 201 in 1970-71. Several individual watershed estimates agree quite well with the observed data.

Table 6.--Measured and predicted annual sediment yield (ac-ft/mi^2) for select semiarid rangeland watersheds (modified from Renard, 1980)

Tank number	Measured yield	Predicted yield					
		PSIAC	Dendy/Bolton	Flaxman[1] (Eq. 5)	Flaxman[1] (Eq.6)	Renard	SWRRB/MUSLE
201 B[2]	0.49	0.29	0.83	-0.180	0.16	0.68	0.25
201 G	0.13	0.19					0.05
207	0.11	0.18	0.73	0.049	0.12	0.61	0.05
208	0.13	0.16	0.75	0.313	0.17	0.62	0.08
212	0.11	0.30	0.62	0.142	0.12	0.53	0.08
213	0.09	0.18	0.69	0.375	0.15	0.58	0.80
214	0.37	0.38	0.70	0.154	0.21	0.59	0.11
215	0.70	0.42	0.85	0.249	0.32	0.69	0.21
216	0.51	0.28	0.76	0.341	0.23	0.63	0.43
223	0.30	0.29	0.83	0.085	0.28	0.68	0.15

[1] Flaxman method includes both eq. 5 and 6 estimates.

[2] The B and G refer to brush and grass cover associated with the 1971 treatment of the watershed.

The values assigned to the nine PSIAC factors were made using some interpolation between the three yield levels defined in the manual. We felt that such interpolation was warranted by our detailed knowledge of the watershed and familiarity with the method (the senior author was a member of the committee which developed the method).

The Flaxman (1972) method, surprisingly, was no better than those of the other methods, even though the Flaxman method was developed specifically for conditions in the western United States. Like the PSIAC method, it has no direct term reflecting watershed area. When the additional parameter is used to reflect the 2-yr frequency annual peak discharge, the results improve. The results of the prediction also improved dramatically when the actual flood series was used to estimate the parameter rather than using the simple estimate of precipitation and converting that value to a peak flow.

The Dendy/Bolton method overestimated sediment yield in all cases. The predictions might have improved slightly if actual runoff data had been used to replace the relationship of eq. 3. Thus, an improvement like that obtained with the Flaxman (1974) method might be expected.

The Renard method also overestimated the sediment yield in all but one case. Predictions might improve if the technique were used to simulate the sediment yield using channel characteristics and observed runoff for each individual watershed, rather than the average conditions with which the model was calibrated, and then simplified to the form shown in eq. 7. For example, some of the ponds had grass swales; in other locations, the channels are more rectangular and contain large amounts of sand which more nearly duplicate the conditions of the large watersheds. Thus, sediment accumulation in tanks with sand channels (208, 214, 216, and 223) would be expected to be closer to the predicted, as observed on all but tank 208. If such a scheme were used, it would be somewhat analogous in detail to the SWRRB/MUSLE technique.

The SWRRB/MUSLE method is considerably more complex and, thus, requires more input data than the other methods. However, its results were not significantly closer to the measured values than those of the other methods. Intuitively, we think the problem is not with the MUSLE part of the scheme but, rather, is associated with the inadequacy of the SCS curve number hydrology option used to produce runoff peaks and volumes commensurate with the observed values. Previous work by Simanton et al. (1973), Hawkins (1978a and 1978b), and others, has illustrated problems with using the CN precipitation/runoff relationship.

SENSITIVITY OF PREDICTED SEDIMENT YIELD TO CURVE NUMBER IN SWRRB/MUSLE

Since most summer runoff events in the Basin and Range Province occur under antecedent moisture condition (AMC) I, SWRRB was modified for the purpose of this paper to accept CN I directly as input instead of requiring calculations from CN II as the program was originally written. Input values for CN I were calculated from the SCS curve number equation using observed rainfall-runoff data for Walnut Gulch and solving for the optimum CN. To test the sensitivity of predicted sediment yield to curve number, the calculated CN values were varied $\pm$ 2 and + 10. The results are similar for each of the tanks studied.

As shown in Fig. 1, predicted sediment yield (with the exception of CN + 10) changes very little, with variations within the range of values of curve number typical for Walnut Gulch.

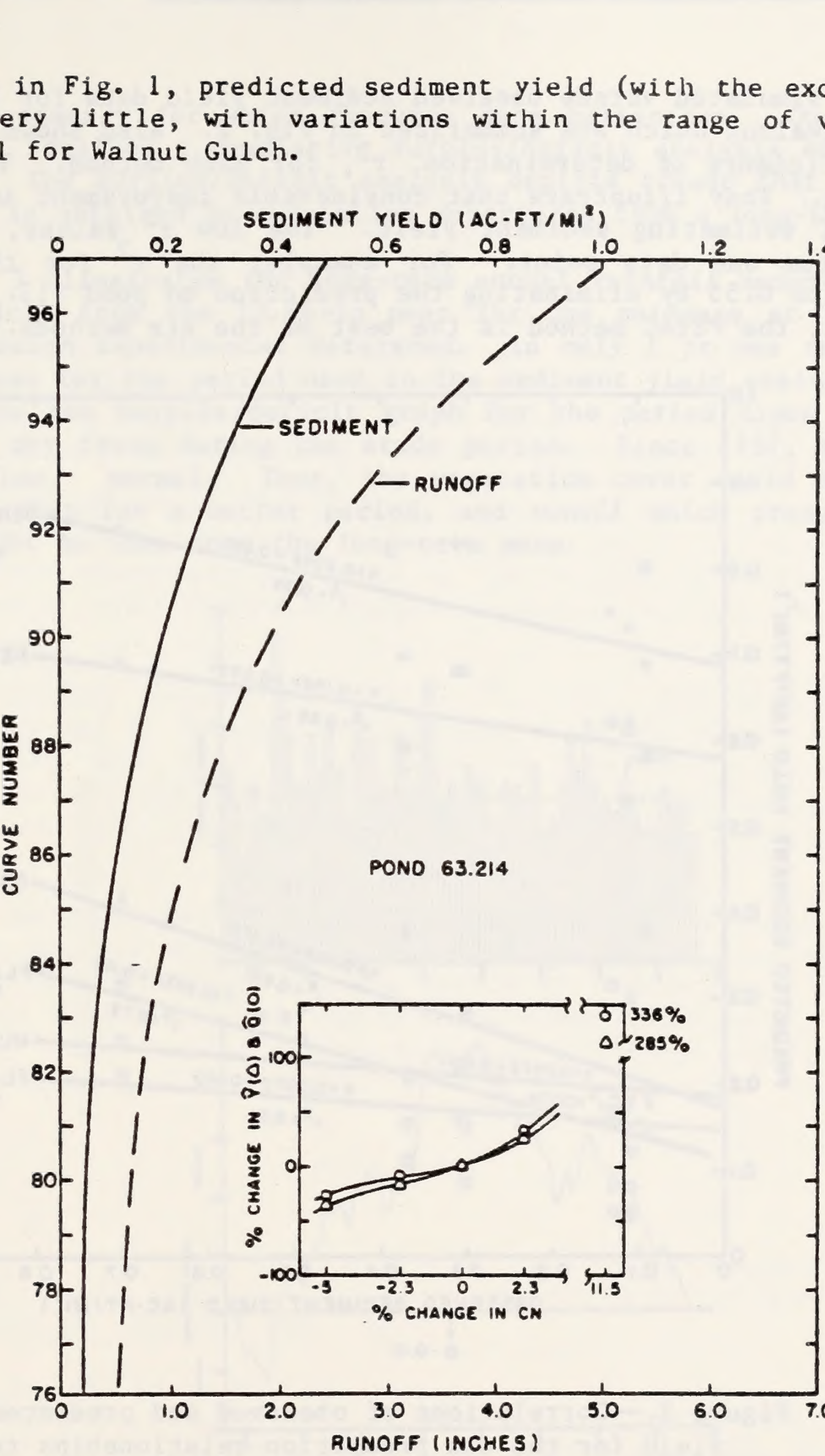

Figure 1.--Sensitivity of runoff and sediment yield to varying curve number.

No sensitivity analysis of sediment yield to the USLE factors (KLSCP) in MUSLE was done since these factors are linearly related to sediment yield and, unlike the runoff factor, remain constant for the period of simulation. However, there is a high potential for error inherent in MUSLE due to the difficulty of evaluating factors like "C" and "K" for a semiarid rangeland environment.

The simulated versus observed sediment yield data for the nine small watersheds on Walnut Gulch are summarized in Fig. 2. Also shown are regression lines and coefficients of determination, r^2, for each method. The results are discouraging. They illustrate that considerable improvement is needed in the technology of estimating sediment yield. The low r^2 values, in most instances, result from one data point. For example, the r^2 for the MUSLE prediction improves to 0.55 by eliminating the prediction on pond 213. From a statistical viewpoint, the PSIAC method is the best of the six methods.

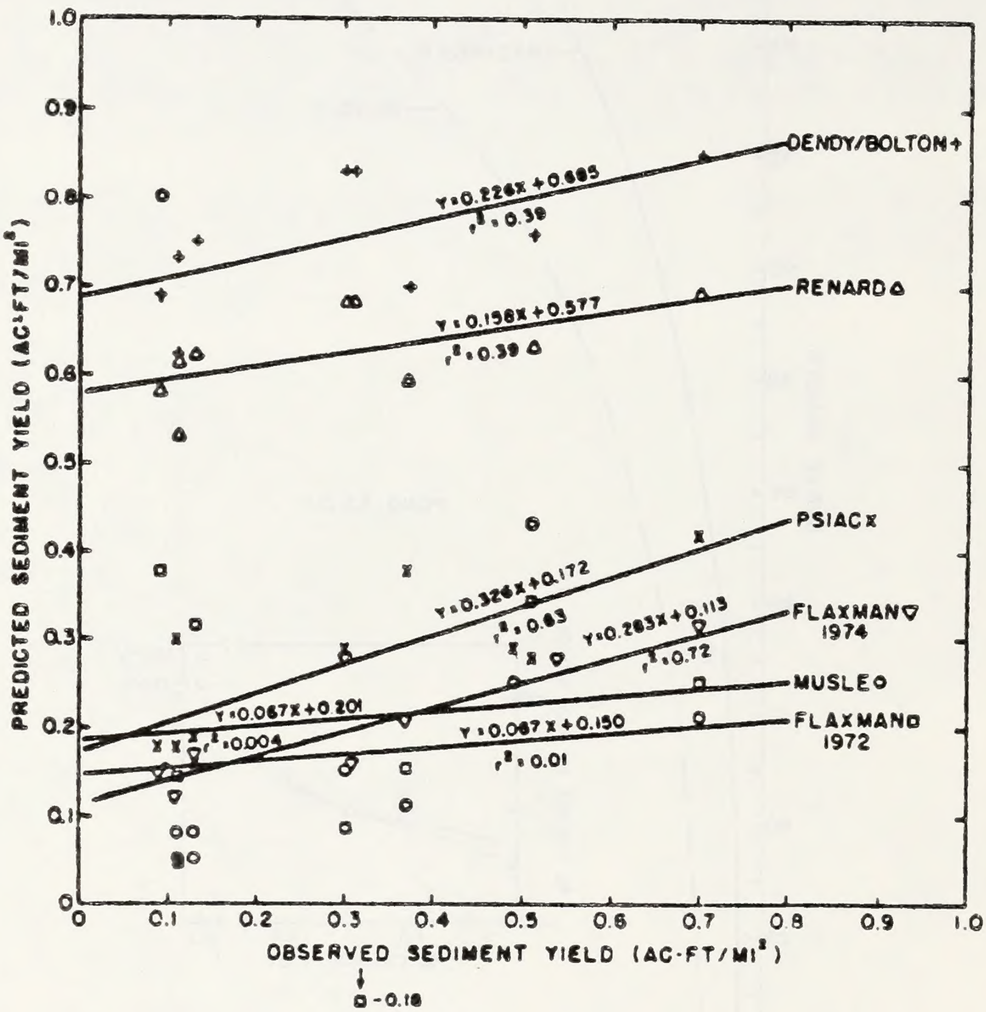

Figure 2.--Correlations of observed and predicted sediment yield for the six prediction relationships tested.

REPRESENTATIVENESS OF SHORT RECORDS

When relatively short records are used in developing and testing prediction schemes, such as the sediment yield methods tested herein, one immediately wonders whether the sample includes all extremes of the climate and if the short-term mean value and standard deviation are the same as that for a long-term record. In the southwestern United States, the coefficient of variation of annual precipitation is maximum for any of the locations considered by Hershfield (1962). Knisel et al. (1979) investigated methods to evaluate the length

of record necessary for water resource data collection. One of the methods investigated involved a cumulative surplus/deficit analysis of the annual precipitation. The surplus/deficit analysis depicts trends that may otherwise be obscure and is obtained by cumulating departures from a long-term mean.

Figure 3 illustrates the long-term annual rainfall amounts and cumulative surplus/deficit from the 13.66-in mean for the raingage at Tombstone, within the Walnut Gulch Experimental Watershed. In only 1 yr was rainfall above the long-term mean for the period used in the sediment yield evaluation. The negative slope to the surplus/deficit graph for the period since 1957 illustrates the general dry trend during the study period. Since 1957, rainfall has been about 8% below normal. Thus, the vegetation cover would be expected to be poorer than that for a wetter period, and runoff which transports the eroded material might be less than the long-term mean.

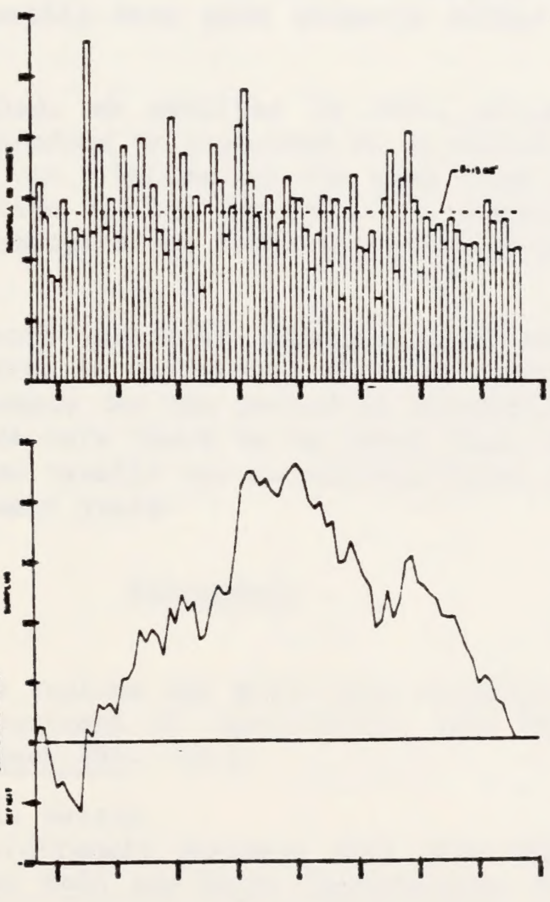

Figure 3.--Annual precipitation and cumulative surplus/deficit for Tombstone, Arizona (Knisel et al., 11).

The importance of an unusual storm in affecting long-term sediment yield trends has been well documented. Thus, it is entirely possible that some of the observed yields are low because of low precipitation/runoff or even the absence of more infrequent events. Stock tanks 214, 215, and 216, on the other hand, have had some large storms during their short records (Osborn and Renard, 1969), which may partly explain why the observed yields for these ponds are larger and somewhat closer for the predicted values.

CONCLUSIONS

1. Predicting sediment yield in the western United States, despite recent developments in water resource models, is difficult and often subjective. The wide variations in watershed characteristics over short distances add to the problem.

2. Of the methods investigated, the PSIAC method appears to give the best results for the amount of work required to make the estimate. The SWRRB/MUSLE method also gave good results (except for pond 213), but the amount of work required for the hydrologic portion of the model is considerable. Certainly, it is potentially a powerful tool for evaluating management practices.

3. Only the PSIAC and the SWRRB/MUSLE methods allow the use of factors (parameters) that reflect management practices. The Renard method also could be used to reflect management practices if the stochastic runoff model and the sediment transport relationship were used directly rather than as simplified with eq. 7.

4. The Flaxman method, as modified in 1974, illustrates some of the improvement which can be obtained by inclusion of an additional term to reflect the 2-yr frequency peak flow. Estimating the peak flow with actual records also improved the correlation between observed and predicted sediment yields over converting the 2-yr precipitation frequency estimate using a rainfall-runoff relationship.

5. The methods tested generally underpredicted sediment yield. The underprediction may, in part, be associated with the questionable representativeness of the climatic sample for the period of observation. Records at all but three of the watersheds were known to be lower than normal in precipitation/runoff, and thus, those results are undoubtedly below what might be considered the mean annual sediment yield.

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Geology
January 1968

PROCEDURE

SEDIMENT STORAGE REQUIREMENTS FOR RESERVOIRS

PROCEDURE FOR DEVELOPING SEDIMENT STORAGE REQUIREMENTS FOR RESERVOIRS

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Figures

This revision of Technical Release No. 12 was prepared by John W. Roehl and includes material contributed by E. M. Flaxman, J. N. Holeman, J. L. Hunt, G. L. Lanman, G. W. Renfro, and E. M. Thorp.

PROCEDURE FOR DEVELOPING SEDIMENT STORAGE REQUIREMENTS FOR RESERVOIRS

GENERAL

To assure the full effectiveness of a reservoir, capacity must be provided in it to offset the depletion of capacity due to sediment accumulation during its design life. Engineering Memorandum-27 (Rev), Supplement 1, establishes the criteria and general procedures needed to determine the required volume of sediment accumulation and its allocation above and below the crest elevation of the principle spillway. Form SCS-309 (Rev. 10-67), Reservoir Sedimentation Design Summary, has been prepared to facilitate recording and computation of the data. This form, figure 1, should be completed by a geologist familiar with the processes of sedimentation. When the form is properly filled out, the design criteria set forth in Engineering Memorandum-27 (Rev), Supplement 1, will be met. A copy of the form should be prepared and filed with other pertinent design information for each reservoir. The recorded data then will be available for use in the final design of reservoirs proposed for either watershed or other program work plans.

Engineering Memorandum-27 (Rev), Supplement 1, states: "The rate of sediment accumulation in a reservoir is dependent on the sediment yield from its drainage area ...." This infers that the sediment yield, as such, must be determined for each reservoir that is being designed. It does not, however, preclude the use of available information concerning rates of sediment accumulation in reservoirs.

The following discussion considers the principles and procedures involved in the sediment design of reservoirs encountered in Service work. Examples to indicate the proper completion of Form SCS-309 (Rev. 10-67) are presented for several types of reservoirs. Methods and procedures referred to but not included in this Technical Release are to conform with National procedures or with procedures approved by the Engineering and Watershed Planning Units.

SEDIMENT YIELDS

There are several ways to determine sediemnt yields or rates of sediment accumulation in reservoirs and these are discussed briefly below.

Gross Erosion and Sediment Delivery Ratios

This means of determining sediment yields has proven quite successful in Service work especially in the more humid areas of the country. It is well adapted for estimating current sediment yields and predicting the influence and effect of land treatment and other measures on future sediment yields. The following simple equation is employed and the sediment yield part of Form SCS-309 (Rev. 10-67) has been designed with this equation in mind.

$$Y = E(DR) \qquad \text{(Equation 1)}$$

SCS-309
Rev. 10-67

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

RESERVOIR SEDIMENTATION DESIGN SUMMARY

WATERSHED ______________ SITE NO. ______ DRAINAGE AREA ______ Sq. Mi. ______ Acres

LOCATION ______________ STATE ______ PURPOSE ______________

DATA COMPUTED BY ______________ TITLE ______________ DATE ______

SEDIMENT YIELD BY SOURCES (AVERAGE ANNUAL)

		PRESENT CONDITIONS			FUTURE (AFTER CONS. TREATMENT)		
		ACRES	SOIL LOSS (TONS/AC)	TOTAL (TONS)	ACRES	SOIL LOSS (TONS/AC)	TOTAL (TONS)
SHEET EROSION	CULTIVATED LAND						
	IDLE LAND						
	PASTURE - RANGE						
	WOODLAND						
	OTHER						

	DELIVERY RATIO (%)		TONS DELIVERED	DELIVERY RATIO (%)		TONS DELIVERED
SHEET EROSION - TOTAL						
GULLY EROSION						
STREAMBANK EROSION						
STREAMBED EROSION						
FLOODPLAIN SCOUR						
OTHER (ROADSIDE ETC.)						
		TOTAL			TOTAL	

DEPOSITION

TEXTURE INCOMING SEDIMENT		
% CLAY	% SILT	% COARSE
VOLUME WEIGHT DEPOSITED SEDIMENT LBS/CU. FT.		
SUBMERGED		
AERATED		

SEDIMENT DELIVERED TO SITE (TONS/YR)		TRAP EFFICIENCY (%)	ANNUAL DEPOSITION (TONS)	DESIGN PERIOD (YRS)	PERIOD DEPOSITION (TONS)	DESIGN DEPOSITION (TONS)
PRESENT						
FUTURE						
FUTURE						
			TOTALS			

SEDIMENT STORAGE REQUIREMENTS

PERIOD (YRS)	CONDITION OF SEDIMENT	% OF TOTAL	DEPOSITION (TONS)	VOLUME WEIGHT	STORAGE REQUIRED		STORAGE ALLOCATION (ACRE FEET)		
				TONS/AC.FT.	ACRE-FEET	WATERSHED INCHES	SEDIMENT POOL	RETARDING POOL	OTHER
	SUBMERGED								
	AERATED								
	SUBMERGED								
	AERATED								
	TOTALS								

Figure 1. Reservoir Sedimentation Design Summary

where: Y = Sediment Yield (tons/unit area/year)
E = Gross Erosion (tons/per unit area/year)
DR = Sediment Delivery Ratio (DR less than 1)

The gross or total erosion in the drainage area of a reservoir is the summation of all erosion occurring in the drainage area. It includes sheet and rill erosion and channel-type erosion (gullies, valley trenches, streambank erosion, etc.). The determination of quantitative values for each type of erosion is outlined in existing guides, handbooks, and technical releases. The sediment delivery ratio, the ratio of sediment yield to gross erosion, is estimated from relationships discussed in various guides and references. The product of the gross erosion and the sediment delivery ratio provides the sediment yield for use in computing the sediment design requirements.

Reservoir Sedimentation Surveys

Reservoir sedimentation surveys are excellent sources of data for establishing sediment yields to reservoirs. Reservoir deposition and sediment yield are not synonymous. To obtain the sediment yield to a surveyed reservoir, the measured rate of deposition in that reservoir must be divided by its estimated trap efficiency. This takes into account that portion of the sediment inflow that is not deposited in the reservoir but passes on through the outlet works. The use alone of the rate of deposition established by a sedimentation survey implies that the trap efficiency of the reservoir being designed is the same as that of the surveyed reservoir, and this is not necessarily the case.

If the results of reservoir sedimentation surveys are available, they may be used for design purposes. Miscellaneous Publication No. 964[1/] provides the data obtained from many reservoir surveys, and information concerning rates of deposition in selected reservoirs representing the area under consideration may be obtained from this publication. If no reservoirs representing the area have been surveyed, it could well prove profitable to conduct sedimentation surveys on selected reservoirs existing in the area. It is important that the period of sedimentation record of reservoirs previously surveyed or contemplated for survey be long enough to insure data that will represent the normal or average conditions.

The drainage areas of any reservoirs on which sedimentation surveys have been or are made for specific sediment design needs must be similar in topography, soils, and land use to that for which the information is desired. In addition, the size of the drainage areas of the surveyed reservoirs should not be less than one-half nor more than

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1/ Summary of Reservoir Sediment Deposition Surveys Made in the United States Through 1960; Agricultural Research Service in cooperation with Subcommittee on Sedimentation, Inter-Agency Committee on Water Resources; Miscellaneous Publication No. 964, U.S. Department of Agriculture, Washington, D. C., May 1964.

twice that of the particular structures being designed if the measured data is to be transposed. Within these limitations, the total annual sediment yield may be adjusted for design use on the basis of the ratio of the drainage areas raised to the 0.8 power in the following manner:

$$S_e = S_m \left(\frac{A_e}{A_m}\right) 0.8 \qquad \text{(Equation 2)}$$

where: S_e = sediment yield to structure being designed, in tons per year
S_m = sediment yield to the surveyed reservoir, in tons per year: measured annual deposition ÷ trap efficiency of surveyed reservoir
A_e = drainage area of reservoir being designed
A_m = drainage area of surveyed reservoir

In consistently mountainous areas, such as the Sierra Nevada, there is no indicated difference in sediment yield per unit area due to size of drainage area. Also, where active channel-type erosion increases downstream as from mainstem channel bank cutting, the sediment yield per unit area may increase with increasing drainage area. Therefore, the relationship must be used with judgment and should be confined generally to the humid areas east of the Rocky Mountains.

Suspended Load Records

Rarely is there time available to establish a suspended load station at a proposed site and obtain sufficient data before the design information is required. However, if suspended load records are available from nearby locations that represent the areas for which the information is required, such data may be used similarly to that obtained by reservoir sedimentation surveys. In the instance of suspended load data, the bedload portion of the sediment yield is not measured, and estimates of this part of the sediment load must be made. It can vary from practically none to 15-20 percent or more of the total load depending upon the type of sediment that is available for transport by the stream.

Direct Predictive Equations

Predictive equations based on watershed and reservoir parameters have been developed in some areas to estimate sediment yield or reservoir sediment accumulation. These equations generally express sediment yield or reservoir sediment accumulation as functions of a combination of several measurable, independent variables. The variables may be reservoir capacity/watershed ratio, annual runoff, size of drainage area, reservoir shape, watershed shape, time, and others.

Such equations are not numerous but, where developed, they may be used with the understanding that their application must be confined to the specific area they represent.

SEDIMENT DEPOSITION

Sediment accumulation in a reservoir is dependent on the sediment yield from its watershed, the trap efficiency, and age of the reservoir. How the accumulated sediment will be distributed within the reservoir basin depends upon the character of the inflowing sediment, the operation of the reservoir, and other factors.

Trap Efficiency

Trap efficiency is the amount (in percent) of the sediment delivered to the site that will remain in the reservoir. It is a function of detention storage time, character of the sediment, nature and character of inflow, and other factors. The trap efficiency is readily estimated on the basis of the ratio of the capacity of the reservoir to the average annual inflow[2/] [3/] using the following procedure.

A. Estimate the total required capacity of the reservoir in inches. This includes the total capacity allocated to floodwater detention, sediment storage, and other uses. Since an actual value for the total capacity cannot be obtained until final design is completed, an approximation of the total capacity is made as follows.

1. Assume, for the physiographic area involved, a reasonable and realistic volume of sediment storage that might be required for the effective life of the structure. For example, 1.5 inches.

2. Obtain from the hydrologist an estimate of the required floodwater detention storage. For example, 4.5 inches.

3. The sum of 1 and 2 is the estimated total capacity of the reservoir. That is, 1.5 + 4.5 = 6.0 inches. If there is additional storage such as storage for water supply, recreation, etc., it must be included in the estimated total. If an estimate of the total required storage is available in terms of acre-feet, it is suggested that this value be converted to watershed inches to simplify the calculation.

B. Determine the average annual runoff, in inches. This value may be from the hydrologic analysis of the watershed, from Hydrologic Investigation, Atlas HA-212[4/], or other available information.

2/ Brune, Gunnar M., Trap Efficiency of Reservoirs, Trans. AGU, Vol. 34, No. 3, pp. 407-418, June 1953.

3/ Gottschalk, L. C., Trap Efficiency of Small Floodwater-Retarding Structures, Conference Preprint 147, ASCE Water Resources Engineering Conference, Mobile, Alabama, March 8-12, 1965.

4/ Busby, Mark W., Annual Runoff in the Conterminous United States, Hydrologic Investigations, Atlas HA-212, U.S. Geological Survey, Washington, D. C., 1966.

For purposes of this illustration, it is estimated to be 17.5 inches.

C. Divide the approximate total capacity, in inches, item A-3 above, by the average annual runoff in inches, item B above, to obtain the capacity-inflow (C/I) ratio. That is, 6.0 ÷ 17.5 = 0.343 C/I ratio.

D. Using the curves in figure 2, the trap efficiency for a given C/I ratio in percent is determined on the vertical axis of the graph. Where incoming sediment is assumed to have an abnormal grain-size distribution such as a predominance of bedload or coarse material or the sediment is highly flocculated, the upper curve of figure 2 should be used to determine the trap efficiency. If the incoming sediment is composed primarily of colloids, dispersed clays and fine silts, the lower curve should be used. The median curve is representative of incoming sediment consisting of a normal distribution of various grain sizes. The texture of the sediment should be estimated on the basis of character of watershed soils and the principal sources of sediment. This estimate will provide a basis for selecting the curve in figure 2 to use in determining the trap efficiency and will also have a bearing on the distribution and allocation of the sediment in various pools.

The curves of figure 2 are not applicable to dry reservoirs without adjustment. Where water flows through ungated outlets below the crest of the principal spillway, trap efficiency may be greatly reduced depending on the size and number of such outlets. If the inflowing sediment is predominantly sand, trap efficiency should be reduced by about 10 percent; if it is chiefly fine textured, about 20 percent.

If it is determined that the incoming sediment is composed essentially of equal parts of clay, silt, and fine sand and the proposed structure will have a submerged sediment pool, the median curve of figure 2 would be used without adjustment. In this instance, with a C/I ratio of 0.343, the trap efficiency would be 95 percent. In a similar situation except that the structure is designed as a dry reservoir, the trap efficiency would be 75 percent.

Design Life

The design life of a reservoir is considered equal to the period required for the reservoir to fulfill its intended purpose or purposes. Structures designed by the SCS in the Watershed Protection and Flood Prevention programs are normally designed for a design life of 50 or 100 years. No matter what length of time is involved for a particular reservoir, provisions must be made to accomodate the expected sediment deposition during the same period. This might involve periodic clean-out of deposited sediment at predetermined intervals during the design life or, as is generally the case, capacity is provided to store all of the expected sediment accumulation for the entire design life.

There are certain restrictions placed on the volume of water that may occupy, until displaced by sediment, the sediment pool of a single-

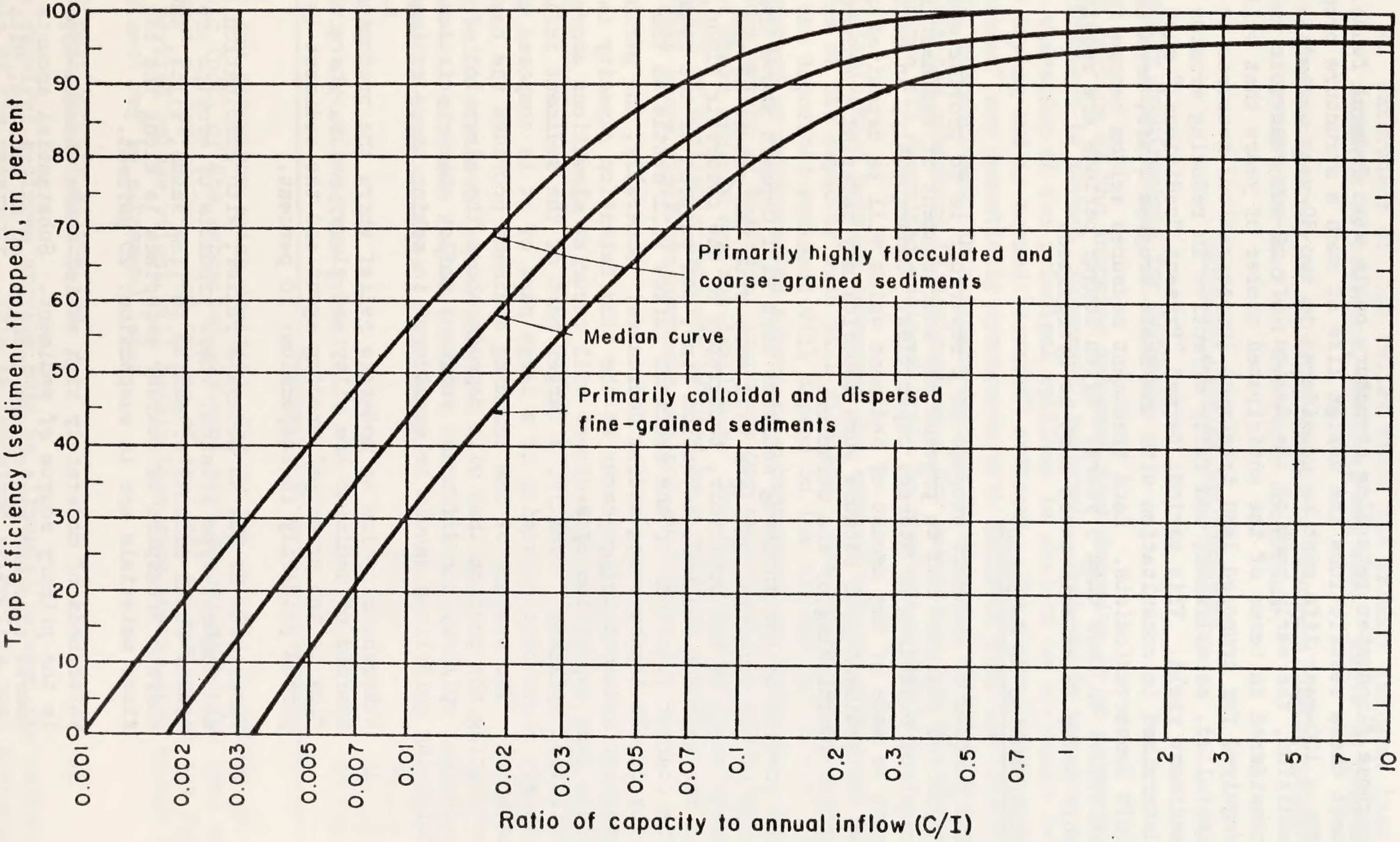

Figure 2. Trap efficiency of reservoirs

purpose floodwater retarding structure built with Federal funds. To meet these restrictions the design life of such a structure proposed for a 100-year life must be considered in two 50-year periods. In addition, the early part of the design life of any reservoir must be considered in terms of the anticipated number of years that will be required for proposed land treatment (conservation) measures to be installed, established, and fully effective in reducing erosion and sediment yield. This period, termed "Present Conditions," must be determined in consultation with the State Program Staff, Area and Work Unit Conservationists. Land treatment measures seldom become fully effective in less than 5 years. Often longer periods are required, and this delay in effectiveness must be recognized.

Distribution of Sediment

The purpose of sediment storage in a reservoir is to provide space for deposited sediment and to prevent the encroachment of sediment in required retarding or storage capacities. Consequently, an estimate must be made of the amount of sediment which will be deposited outside of the sediment pool because such deposits may materially affect the proper functioning of the structure.

The portion of the incoming sediment that will deposit above the elevation of the principal spillway will vary with the nature of the sediment, shape of the reservoir, topography of the reservoir floor, nature of the approach channel, detention time, and purpose of the reservoir. The coarser fractions of the sediment inflow will settle as the velocity of the transporting medium decreases. Generally, the periods of greatest sediment inflow occur at the time detention capacity is being used, thus deposition of sediment will occur at elevations above the principal spillway. Usually, a larger part of the sediment inflow will deposit above this elevation if a large part of it is composed of coarse material. The texture of the incoming sediment provides the basis for estimating the portion that will deposit above the elevation of the principal spillway for different sediment inflow characteristics. The following guidelines should be considered in making these estimates:

1. Watersheds of low to moderate relief where the predominant sources of sediment are silty and clayey soils, where sheet flow is the principal eroding agent and the sediment is transported primarily in suspension: 10 percent.

2. Watersheds of low to moderate relief, with combination sheet and channel-type erosion, where products of erosion are essentially equal amounts of medium to fine sands, silts, and clays. Transport of coarser materials is along the bed and finer materials are in suspension: 20 percent.

3. Watersheds of moderately high relief where channel-type erosion is the primary source of sediment. Substantial amounts of coarse sand and gravel are transported as bedload, with smaller amounts of fine-grained sediment transported in suspension: 30 percent.

4. Watersheds of high relief where the primary sediment load consists of boulders, cobbles, and sand: above 30 percent.

These percentages may be adjusted upward or downward, using judgment based on local watershed and reservoir conditions.

SEDIMENT STORAGE REQUIREMENTS

Capacity Requirements for Sediment

That portion of the incoming sediment that deposits in an underwater environment is termed "submerged" sediment. That which deposits above the elevation of the principal spillway is subject to alternate wetting and drying and is termed "aerated" sediment. The terms "submerged" and "aerated" are essentially synonymous with sediment pool and retarding pool, respectively, in a single-purpose floodwater retarding structure unless the structure is designed as a dry reservoir. In the latter instance all deposited sediment would be considered aerated.

The distinction between submerged and aerated sediments is important in terms of the capacity each will displace. The ultimate volume occupied by the deposited sediment will depend on its texture and whether it is submerged or subjected to alternate submergence and aeration. The volume weight of sediment, in pounds per cubic foot, is based on judgment where records are not available. The following table based on analysis of available data may be used as a guide to selection of volume weights where field measurements are not available.

Grain Size	Submerged (lbs/cu.ft.)	Aerated (lbs/cu.ft.)
Clay	40-60	60-80
Silt	55-75	75-85
Clay-silt mixtures (equal parts)	40-65	65-85
Sand-silt mixtures (equal parts)	75-95	95-110
Clay-silt-sand mixtures (equal parts)	50-80	80-100
Sand	85-100	85-100
Gravel	85-125	85-125
Poorly sorted sand and gravel	95-130	95-130

For any structure being designed, the volume weight, in pounds per cubic foot, of the deposited sediment must be estimated for each environment of deposition. Any volume of sediment determined on the basis of aerated volume weight will retain that same volume even though the sediment may be submerged later.

Sediment Storage Allocation

The required sediment storage must be allocated between the various pools of the reservoir. This is important as certain pool elevations

and flood-routing procedures are dependent upon the expected distribution of the sediment within the reservoir. Engineering Memorandum-27 (Rev.) provides the following definitions which must be kept in mind as the allocations are made. *Sediment storage* is the volume allocated to total sediment accumulation. The *sediment pool* is the reservoir space allotted to the accumulation of submerged sediment during the life of the structure. The *sediment pool elevation* is the elevation of the surface of the anticipated sediment accumulation at the dam. In addition, *sediment reserve* is defined as the volume of the sediment pool required for the second 50-year period in a single-purpose floodwater retarding reservoir designed for a 100-year life.

The following general guidelines are presented to assist in allocating the sediment storage for several situations. They are primarily concerned with reservoirs in which the major portion of the sediment will deposit in a submerged environment. If the structures are designed as "dry" reservoirs, the same guidelines will apply except that all sediment volumes will be based on aerated volume weights.

A. Single-Purpose Floodwater Retarding Reservoirs

1. Single-stage principal spillway

a. In a 50-year life structure, the sediment pool elevation determines the crest elevation of the principal spillway. Since water is expected to occupy this space until displaced by sediment, the sediment volume will be computed using submerged volume weights. The volume of the sediment expected to deposit in the retarding pool will be computed using aerated weights.

b. In a 100-year life structure, the sediment pool elevation as computed for the first 50-year period determines the crest elevation of the principal spillway to be constructed for this period. Since water is expected to occupy this space until displaced by sediment, the sediment volume will be computed using submerged volume weights.

The volume of the sediment pool, or sediment reserve, required for the second 50-year period will also be determined by using submerged volume weights. This is necessary as it is assumed that structural modifications will be made to the principal spillway at the end of 50 years that will raise its elevation to that required for the additional amount of sediment. Submerged volume weights must be used as, with the assumed modifications, water is expected to occupy this capacity until displaced by sediment.

During the first 50-year period, it is known that some sediment will deposit and be subjected to aeration in the capacity allotted to the sediment reserve. Depending on erosion rates, character of the sediment, and operation of the reservoir, this volume may be significant. It is

recommended that the geologist consider each structure individually and determine the need for such allocation.

2. Two-stage principal spillway

   a. In a 50-year life structure, the sediment pool elevation determines the elevation of the low-stage inlet of a two-stage principal spillway. Since water is expected to occupy this space until displaced by sediment, the volume will be computed using submerged volume weights.

      It is known that some sediment will deposit between the elevations of the low-stage and high-stage inlets. The geologist will determine the need for such allocation and will compute the volume using aerated volume weights. That portion of the sediment storage expected to occur in the retarding pool will be computed using aerated volume weights.

   b. In a 100-year life structure, the first 50-year sediment pool elevation determines the elevation of the crest of the low-stage inlet. Since water is expected to occupy this space until displaced by sediment, this volume will be computed by using submerged volume weights.

      The original construction plans of the principal spillway should provide for the crest of the high-stage inlet to be built at the elevation required at the end of the 100-year period. It is assumed that structural modifications will be made to the principal spillway at the end of 50 years to raise the elevation of the low-stage inlet to that required for the additional amount of sediment. Since it is assumed that water will occupy the space below this higher elevation of the low-stage inlet during the second 50-year period, the sediment volume will be computed using submerged volume weights.

      It is known that some of the sediment will deposit and be subjected to aeration in the retarding pool between the low and high-stage inlets as well as in that above the high-stage inlet. This will occur during both 50-year periods and a portion will be included in the capacity provided for submerged sediment during the second 50 years (sediment reserve). The geologist will make provisions for the capacity required below and above these several elevations for this sediment and the volume will be computed using aerated volume weights.

B. Multiple-Purpose Reservoirs

The sediment pool in multiple-purpose reservoirs will be planned as one pool for the entire evaluated economic life of the structure (normally one hundred years), and its volume will be based on submerged volume weights. The capacity for beneficial water storage

should be added to that required to contain the submerged sediment. The portion of the sediment that will deposit above the elevation of the principal spillway will be determined in accordance with the general guidelines previously discussed. The volume of such sediment will be computed on the basis of aerated volume weights.

A multiple-purpose structure may be designed with either a single-stage or two-stage principal spillway. If a two-stage principal spillway is used, consideration must be given to the distribution of the sediment between the elevations of the low and high-stage inlets as well as that above the elevation of the high-stage inlet. The volume of this sediment will be computed on the basis of aerated volume weights.

It is suggested that procedures for allocation of sediment storage considered necessary but not specifically covered in this Technical Release be developed in consultation with the Engineering and Watershed Planning Unit.

COMPLETION OF FORM SCS-309 (Rev. 10-67)

Certain basic background information is necessary concerning every reservoir being designed. The approximate location of the structure must be indicated on an aerial photograph, a USGS quadrangle, or other suitable map so that the watershed and problem areas above the site can be delineated and measured. An estimate of the total required reservoir capacity for all purposes must be made.

The several major parts of the form are considered separately in the following discussions.

1. <u>Heading</u>

Most of the information required in the heading is self-explanatory. The drainage area refers to the drainage area above the site of the structure. The purpose of the reservoir should be stated as: Single-purpose--flood prevention; Multiple-purpose--flood prevention and water supply; or whatever purpose may be involved. Any additional pertinent information concerning the structure such as single or two-stage riser should be noted in the space to the left and below the heading.

An example of the heading is shown below.

SCS-309
Rev. 10-67

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

RESERVOIR SEDIMENTATION DESIGN SUMMARY

WATERSHED Blank Creek SITE NO. 7 DRAINAGE AREA 3.44 Sq. Mi. 2200 Acres

LOCATION Photo No. ASI-131 STATE Midstate PURPOSE Single-purpose—FP

DATA COMPUTED BY James Jones TITLE Geologist DATE 12/15/67

2. Sediment Yield by Sources (Average Annual)

a. Gross Erosion and Sediment Delivery Ratios

As stated earlier, Form SCS-309 (Rev. 10-67) was designed with the relationship of gross erosion and sediment delivery ratios to sediment yield (Equation 1) in mind. Thus, this part of the form concerns estimates of erosion occurring in the drainage area of the reservoir and the sediment delivery ratios.

The estimates of the annual amounts of erosion must be realistic and reasonable, both for "Present conditions" and for "Future (After Conservation Treatment)." Normally these estimates are developed by delineating problem areas in the drainage area and computing sheet erosion and the other components of the total erosion as individual items. Separate work sheets are generally used for this purpose and only totals for each component of the erosion need be indicated in the appropriate spaces on the form. It would be preferable, however, to show the acreages and rates of soil loss for each land use listed under "Sheet Erosion." The "Soil Loss (Tons/Ac)" for sheet erosion values is to be developed in conformance with existing guides and releases prepared by the Engineering and Watershed Planning Units. The basic information required for this determination may be obtained from soil survey data available in Work Unit offices and any supplementary field investigations as may be necessary.

The "Future (After Conservation Treatment)" data should be computed using the most realistic information available. Land treatment data provided by the Work Unit Conservationist should be reflected in predicting reductions in erosion rates from the various sediment sources. These future reductions must be realistic and should be attainable.

The total amounts of material eroded by channel-type processes (gullies, streambanks, etc.) for both present and future conditions are estimated on the basis of field reconnaissance or detailed study using available aerial photographs and soil survey data. If the volume of sediment produced by gullying is determined by the procedure outlined in Technical Release No. 32, "Procedures for Determining Rates of Land Damage, Land Depreciation and Volume of Sediment Produced by Gully Erosion," dated July 1966, the tons of eroded material so obtained should be used. Information concerning streambank erosion and flood-plain scour often can be obtained from the flood-plain damage survey. If the streambed is degrading and is a source of sediment, procedures to determine annual amounts of streambed erosion should be developed in consultation with the Engineering and Watershed Planning Unit. The total amount of material eroded by these processes is entered in the appropriate spaces on the form. The work sheets used

in developing the erosion information should be filed with Form SCS-309 (Rev. 10-67) as supporting data.

The next step in completing this part of the form is concerned with sediment delivery ratios and the computation of sediment yield at the structure site. The percent of eroded material that reaches the site should be realistically estimated for each component of the erosion. Various guides for estimating sediment delivery ratios in terms of watershed parameters have been prepared by the several Engineering and Watershed Planning Units, and these guides should be consulted to obtain values to enter in the appropriate spaces. The item "Tons Delivered" is the product of the total soil loss for each component of the erosion and the "Delivery Ratio (%)" for that component. The sum of these products is the sediment yield for "Present" and "Future" conditions.

Where upstream structures control sediment, the erosion and sediment yield are determined using the foregoing procedure only for the net drainage area below the upstream structures.

b. Data from Reservoir Sedimentation Surveys

If sediment yields based on transposed data obtained from reservoir sedimentation surveys are to be used, the values so obtained are entered in the total "Tons Delivered" spaces of this part of the form. Unless there is strong evidence to support an estimate of a difference between "Present" and "Future" yields, the same values should be used in these respective spaces.

It should be stated on the form that sedimentation surveys were used to develop the values. The source of the data and the work sheets used in developing the information should be filed with the form.

c. Data from Suspended Load Records

Sediment yield information obtained and transposed from suspended load stations is entered on the form in the same manner as that obtained from reservoir sedimentation surveys. A statement that suspended load records were used should be placed on the form. The supporting data, including a listing of the stations used, should be filed with the form.

d. Data Developed by Direct Predictive Equations

If a predictive equation to determine sediment yield is used, the computed value of the sediment yield is to be entered in the appropriate spaces for total "Tons Delivered." The equation used should be noted on the form, and the work sheets involved in the solution of the equation should be filed with it.

An example of this part of the form follows.

SEDIMENT YIELD BY SOURCES (AVERAGE ANNUAL)

		PRESENT CONDITIONS			FUTURE (AFTER CONS. TREATMENT)		
		ACRES	SOIL LOSS (TONS/AC)	TOTAL (TONS)	ACRES	SOIL LOSS (TONS/AC)	TOTAL (TONS)
SHEET EROSION	CULTIVATED LAND 1/	540	18.5	9990 2/	500	12.9	6450 2/
	IDLE LAND	150	8.1	1215			
	PASTURE - RANGE	880	4.1	3610	950	2.9	2755
	WOODLAND	630	2.3	1450	750	1.5	1125
	OTHER						

	DELIVERY RATIO (%)		TONS DELIVERED	DELIVERY RATIO (%)		TONS DELIVERED
SHEET EROSION - TOTAL	20	16265	3255 2/	20	10330	2065 2/
GULLY EROSION	80	6600	5280	80	3160	2530
STREAMBANK EROSION	90	1200	1080	90	1200	1080
STREAMBED EROSION						
FLOODPLAIN SCOUR						
OTHER (ROADSIDE ETC.)	50	2000	1000	50	800	400
		TOTAL	10615 3/		TOTAL	6075 4/

1/ Includes row crops, small grains, meadow.

2/ Product of preceding two columns rounded to nearest five tons.

3/ To be entered under column "Sediment Delivered to Site" in "Present" space of "Deposition" part of form.

4/ To be entered under column "Sediment Delivered to Site" in "Future" space of "Deposition" part of form. This will be entered in one or both "Future" spaces depending upon the type and design life of the structure.

3. Texture and Volume Weight

The estimated texture of the incoming sediment is to be entered in the spaces provided. The volume weight, in pounds per cubic foot, for submerged and aerated deposited sediment is based on the estimated texture and the guidelines presented in the table on page 9. These values are entered in the appropriate spaces on the form.

4. Deposition

This part of the form is provided to compute the amount of sediment delivered to the site that will deposit in the reservoir. Three lines are provided to facilitate computations of sediment deposition in two 50-year periods. The first two lines, indicated as "Present" and Future," are used for the first 50-year period, and the third line, indicated as "Future," is used for the second 50-year period. For a single-purpose floodwater retarding structure with a design life of 50 years or for a multiple-purpose structure with a design life of either 50 or 100 years, entries need be made only in the first two lines. Each column in this part of the form is discussed below.

a. Sediment Delivered to Site (Tons/Yr)

The values for the sediment yield, the total "Tons Delivered" previously computed, are entered in the appropriate spaces "Present" and "Future."

To allow for the gradual improvement of watershed conditions during the period of installation of land treatment measures and the period during which these measures become effective in reducing erosion, an average sediment yield between the calculated present and future rates may be used for the "Present."

b. Trap Efficiency

The trap efficiency is estimated on the basis of the discussions presented on pages 5 and 6. The value is entered in this column. There is insufficient data available at this time to predict the change in trap efficiency with increasing life of a reservoir. Therefore the same value for the trap efficiency of a given reservoir should be used for both present and future conditions.

c. Annual Deposition (Tons)

The "Annual Deposition (Tons)" is the product of "Sediment Delivered to Site (Tons/Yr)" and the "Trap Efficiency (%)" for each line.

d. Design Period (Yrs)

The "Design Period" for "Present" conditions is the anticipated number of years that will be required for the proposed land treatment measures to be installed and become fully established and effective in reducing erosion and sediment yield.

The "Design Period" for the second line, indicated as "Future," for a single-purpose floodwater retarding structure with a 100-year design life will be the difference between 50 years and the "Design Period" for "Present" conditions. The "Design Period" for the third line, indicated as "Future," is the remaining design life of the structure. In the instance of a 100-year life single-purpose floodwater retarding structure, this is 50 years. Provision is thus made for two 50-year periods.

In the instance of a structure being designed for a 50-year life only the first two lines of this part of the form are used. Similarly, for a multiple-purpose structure with a design life of 100 years, the first two lines are the only ones to be used. In this latter instance, the "Design Period" for the "Future" would be the difference between 100 years and the "Design Period" for "Present" conditions.

e. Period Deposition (Tons)

The "Period Deposition" is the product of the "Annual Deposition" and the corresponding number of years for each "Design Period."

f. Design Deposition (Tons)

The column "Design Deposition" when completed provides the information needed to determine sediment storage requirements. The first open space in this column is provided to enter the sum of the values noted in the first two spaces under "Period

Deposition." The values to be entered in the second open space of this last column will equal the value recorded in the third space of the preceding column. This makes available for further computations the amount of deposition expected to occur in each of the two 50-year periods necessary for consideration in the sediment design of a 100-year life single-purpose floodwater retarding structure.

The "total" space of this last column is the sum of the values for the two (if used) "Design Deposition" values. This sum represents the total amount of sediment, in tons, that will be deposited in the reservoir during the designed effective life of structure.

As noted earlier, direct predictive equations may be used to determine sediment yields. In some instances predictive equations are developed to estimate the total deposition, in tons, within a reservoir during a period of time. The sediment yield, trap efficiency, and life of the reservoir generally are among the variables incorporated in such equations. If such an equation is used, it is necessary to enter only the estimated deposition for the required time periods in the last column of this part of the form.

The following examples illustrate the use of this part of the form for several different situations.

(1) 50-Year Life Reservoir--Any Purpose

SEDIMENT STORAGE REQUIREMENTS

PERIOD (YRS) 1/	CONDITION OF SEDIMENT 2/	% OF TOTAL 2/	DEPOSITION (TONS) 3/	VOLUME WEIGHT 4/	STORAGE REQUIRED 5/		STORAGE ALLOCATION (ACRE FEET) 6/		
				TONS/AC.FT.	ACRE-FEET	WATERSHED INCHES	SEDIMENT POOL	RETARDING POOL	OTHER
50	SUBMERGED	80	258,415	1089	237.3	1.29	237.3		
	AERATED	20	64,605	1786	36.2	0.20		36.2	
	SUBMERGED								
	AERATED								
50	TOTALS		323,020		273.5	1.49	237.3 7/	36.2 8/	

1/ See discussion on page 6 and item 4d on page 16.

2/ See discussion on page 8.

3/ See item 5d on page 19.

4/ See item 5e on page 19.

5/ See item 5f on page 20.

6/ Guidelines given on pages 9-12.

7/ This capacity establishes the crest elevation of the principal spillway.

8/ This capacity must be added to the required floodwater retarding volume to establish the elevation of the emergency spillway.

(2) 100-year life reservoir - single-purpose floodwater retarding reservoir.

TEXTURE INCOMING SEDIMENT		
% CLAY	% SILT	% COARSE
30	40	30
VOLUME WEIGHT DEPOSITED SEDIMENT LBS/CU. FT.		
SUBMERGED	50	
AERATED	82	

DEPOSITION

	SEDIMENT DELIVERED TO SITE (TONS/YR) 1/	TRAP EFFICIENCY (%)	ANNUAL DEPOSITION (TONS)	DESIGN PERIOD (YRS) 2/	PERIOD DEPOSITION (TONS)	DESIGN DEPOSITION (TONS)
PRESENT	10615	95	10085	8	80680	
FUTURE	6075	95	5770	42	242340	323020 3/
FUTURE	6075	95	5770	50	288500	288500 4/
			TOTALS	100		611520

1/ Entries from "Sediment Yield" part of form.

2/ See item 4d on page 16.

3/ This value to be used in first 50-year period for distribution in "Sediment Storage Requirements" part of form.

4/ This value to be used for second 50-year period for distribution in "Sediment Storage Requirements" part of form.

(3) 100-year life reservoir - multiple purpose.

TEXTURE INCOMING SEDIMENT		
% CLAY	% SILT	% COARSE
30	40	30
VOLUME WEIGHT DEPOSITED SEDIMENT LBS/CU. FT.		
SUBMERGED	50	
AERATED	82	

DEPOSITION

	SEDIMENT DELIVERED TO SITE (TONS/YR) 1/	TRAP EFFICIENCY (%)	ANNUAL DEPOSITION (TONS)	DESIGN PERIOD (YRS) 2/	PERIOD DEPOSITION (TONS)	DESIGN DEPOSITION (TONS)
PRESENT	10615	95	10085	8	80680	
FUTURE	6075	95	5770	92	530840	611520
FUTURE						
			TOTALS	100		611520 3/

1/ Entries from "Sediment Yield" part of form.

2/ See item 4d on page 16.

3/ This total to be used for distribution for entire 100-year period in "Sediment Storage Requirements" part of form.

5. Sediment Storage Requirements

This part of the form is used for estimating the distribution and allocation of required capacity for sediment accumulation in the various pools to be included in the reservoir.

a. Period (Yrs)

This column provides for the two periods of time needed to develop the sediment design for a single-purpose floodwater retarding reservoir with a 100-year life. In the first space, in this instance, would be noted "first 50 years" and in the second space would be noted "second 50 years." For any structure being designed with a 50-year life, only the first space would be used and "50 years" would be noted therein. Similarly, for a multiple-purpose reservoir being designed with a 100-year

life, only the first space would be used and "100 years" would be noted therein.

b. Condition of Sediment

This column is self-explanatory and provides headings indicating the expected condition of the sediment, whether submerged or aerated, for use in the computation.

c. Percent (%) of Total

This column makes provisions to enter values for the estimated protions of the incoming sediment that will deposit in submerged and aerated environments during the periods being considered. The values used should be in conformance with the guidelines previously discussed.

There is little information available that will predict differences in the environment of sediment deposition within a reservoir with its increasing age. Therefore it is suggested that the same percentages be used during the entire design life of the reservoir. For a 100-year life single-purpose floodwater retarding reservoir, this would mean using the same percentage distribution for each of the two 50-year periods.

d. Deposition (Tons)

This fourth column provides the spaces to enter the amounts of the estimated sediment deposition, in tons, previously determined in the "Deposition" part of the form. The total "Design Deposition" as previously determined is entered in the "Total" space of this column. In the instance of a single-purpose floodwater retarding reservoir with a design life of 100 years, the same "Design Deposition" is entered in the "Total" space of this column. However, the "Design Deposition" previously computed and entered in the first and second spaces of the last column of the "Deposition" part of the form must be used for the first 50-year period and the second 50-year period, respectively. No spaces for recording these values are provided in this part of the form, and a separate worksheet will be necessary to facilitate the computation.

The "Design Deposition" values are multiplied by the corresponding percentage values of the preceding column to arrive at the number of tons of sediment expected to be deposited under submerged and aerated conditions. These values are entered in the appropriate spaces of this fourth column.

e. Volume Weight (Tons/Ac. Ft.)

The tons of sediment deposited in the reservoir must be expressed in terms of the volume it will displace. The volume weight entered in the small box "Volume Weight, Deposited Sediment

(lbs/cu.ft.)" is converted to tons per acre foot by the following equation:

$$\text{Tons/Ac.Ft.} = \text{lbs/cu.ft.} \times 21.78$$

The conversions for both submerged and aerated sediment are made and the values entered in the corresponding spaces of this column.

f. Storage Required

(1) The acre-feet of storage required is obtained by dividing the "Deposition (Tons)" by the corresponding "Volume Weight, (Tons/ac.ft.)" for each condition of sediment. The sum of the values in this column is the total capacity required in the reservoir for sediment storage. The values recorded in the individual spaces in this column are distributed among the various pools indicated in the last three columns of this part of the form.

(2) The column "Watershed Inches" is used to express the acre-feet of sediment shown in the sixth column in equivalent watershed inches. The values are obtained by the equation:

$$\text{Watershed Inches} = 0.01875\left(\frac{\text{acre feet of sediment storage}}{\text{drainage area in square miles}}\right)$$

g. Storage Allocation

As stated earlier, the required sediment storage must be allocated between the various pools in the reservoir. The guidelines previously presented indicate how these allocations are to be considered.

Where equations have been developed to predict the total sediment accumulation, in acre-feet, expected in a reservoir during its entire life, the results may be entered in the total "Storage Required" space of the form. Storage allocations can be made from this value. In some instances these equations will predict the distribution and allocation of the deposited sediment. In such cases the information may be used, and the predicted allocations should be entered in the appropriate spaces of the form. The use of such equations should be noted on the form and any work sheets used in the computation should be filed with it.

The following examples are presented to facilitate an understanding of the completion of the "Sediment Storage Requirements" part of the form.

1. Single-purpose floodwater retarding reservoirs

a. Single-stage principal spillway

(1) 50-year design life

1/		
TEXTURE INCOMING SEDIMENT		
% CLAY	% SILT	% COARSE
30	40	30
VOLUME WEIGHT DEPOSITED SEDIMENT LBS/CU. FT.		
SUBMERGED	50	
AERATED	82	

DEPOSITION

	SEDIMENT DELIVERED TO SITE (TONS/YR) 2/	TRAP EFFICIENCY (%) 3/	ANNUAL DEPOSITION (TONS) 4/	DESIGN PERIOD (YRS) 5/	PERIOD DEPOSITION (TONS) 6/	DESIGN DEPOSITION (TONS)
PRESENT	10615	95	10085	8	80680	
FUTURE	6075	95	5770	42	242340	323020 7/
FUTURE						
			TOTALS	50		323020 8/

1/ See item 3 on page 15.

2/ Entries from "Sediment Yield" part of form.

3/ See item 4b on page 16.

4/ Product of 2/ and 3/ to nearest five tons.

5/ See item 4d on page 16.

6/ Product of 4/ and 5/.

7/ Sum of values entered in the first two spaces of 6/.

8/ To be used in "Sediment Storage Requirements" part of form.

(2) 100-year design life

SEDIMENT STORAGE REQUIREMENTS

PERIOD (YRS)	CONDITION OF SEDIMENT	% OF TOTAL 1/	DEPOSITION (TONS)	VOLUME WEIGHT TONS/AC.FT.	STORAGE REQUIRED ACRE-FEET	STORAGE REQUIRED WATERSHED INCHES	STORAGE ALLOCATION (ACRE FEET) SEDIMENT POOL	STORAGE ALLOCATION (ACRE FEET) RETARDING POOL	STORAGE ALLOCATION (ACRE FEET) OTHER
1st 50 yrs.	SUBMERGED	80	258,415	1089	237.3	1.29	237.3 2/		
	AERATED	20	64,605	1786	36.2	0.20	25.4 3/	10.8	
2nd 50 yrs.	SUBMERGED	80	230,800	1089	211.9	1.16	211.9		
	AERATED	20	57,700	1786	32.3	0.18		32.3	
100	TOTALS		611,520		517.7	2.83	474.6 4/	43.1 5/	

1/ See item 5c on page 19.

2/ Establishes crest elevation of principal spillway for first 50-year period.

3/ Deposited in second 50-year sediment pool (sediment reserve) during first 50-year period.

4/ Establishes crest elevation of principal spillway for second 50-year period.

5/ This capacity must be added to the required floodwater retarding volume to establish the elevation of the emergency spillway.

b. Two-stage principal spillway

(1) 50-year design life

SEDIMENT STORAGE REQUIREMENTS

PERIOD (YRS)	CONDITION OF SEDIMENT	% OF TOTAL	DEPOSITION (TONS)	VOLUME WEIGHT	STORAGE REQUIRED		STORAGE ALLOCATION (ACRE FEET)		
				TONS/AC.FT.	ACRE-FEET	WATERSHED INCHES	SEDIMENT POOL	RETARDING POOL	OTHER 1/
50	SUBMERGED	80	258,415	1089	237.3	1.29	237.3		
	AERATED	20	64,605	1786	36.2	0.20		10.8	25.4
	SUBMERGED								
	AERATED								
50	TOTALS		323,020		273.5	1.49	237.3 2/	10.8 3/	25.4 4/

1/ Retarding pool between low and high stage inlets.

2/ Establishes crest elevation of low stage inlet.

3/ This volume must be added to required retarding capacity above the elevation of the high stage inlet to establish the elevation of the emergency spillway.

4/ This volume must be added to required retarding capacity between the low and high stage inlets to establish the elevation of the high stage inlet.

(2) 100-year design life

SEDIMENT STORAGE REQUIREMENTS

PERIOD (YRS)	CONDITION OF SEDIMENT	% OF TOTAL	DEPOSITION (TONS)	VOLUME WEIGHT	STORAGE REQUIRED		STORAGE ALLOCATION (ACRE FEET)		
				TONS/AC.FT.	ACRE-FEET	WATERSHED INCHES	SEDIMENT POOL	RETARDING POOL	OTHER 1/
1st 50 yrs.	SUBMERGED	80	258,415	1089	237.3	1.29	237.3 2/		
	AERATED	20	64,605	1786	36.2	0.20	17.8 3/	10.8	7.6
2nd 50 yrs.	SUBMERGED	80	230,800	1089	211.9	1.16	211.9		
	AERATED	20	57,700	1786	32.3	0.18		12.9	19.4
100	TOTALS		611,520		517.7	2.83	467.0 4/	23.7	27.0 5/

1/ Detention capacity between low and high stage inlets.

2/ Establishes crest elevation of low stage inlet at 50 years.

3/ Deposited in second 50-year sediment pool (sediment reserve) during the first 50 years.

4/ Establishes crest elevation of low stage inlet at 100 years.

5/ Deposited in retarding pool between low and high stage inlets at end of 100 years.

Note: The sum of the values in 4/ and 5/ plus the required floodwater retarding capacity between the low and high stage inlets establishes the elevation of the high stage inlet at 100 years to be provided in the original construction plans.

2. Multiple-Purpose Reservoir - 100-year design life

SEDIMENT STORAGE REQUIREMENTS

PERIOD (YRS)	CONDITION OF SEDIMENT	% OF TOTAL	DEPOSITION (TONS)	VOLUME WEIGHT	STORAGE REQUIRED		STORAGE ALLOCATION (ACRE FEET)		
				TONS/AC.FT.	ACRE-FEET	WATERSHED INCHES	SEDIMENT POOL	RETARDING POOL	OTHER 1/
100	SUBMERGED	80	489,215	1089	449.2	2.45	382.2		67.0 2/
	AERATED	20	122,305	1786	68.5	0.37		68.5	
	SUBMERGED								
	AERATED								
100	TOTALS		611,520		517.7	2.82	382.2 3/	68.5	67.0 4/

1/ Beneficial water storage.

2/ Portion of submerged sediment allocated to beneficial storage pool to be based on the judgment of the geologist in consultation with the Engineering and Watershed Planning Unit.

3/ Submerged sediment in sediment pool.

4/ Submerged sediment deposited in capacity for beneficial use.

Note: The required capacity for beneficial use must be added to the sum of 3/ and 4/ to establish the crest elevation of the principal spillway.

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Modeling Evapotranspiration from Sagebrush-Grass Rangeland

J. ROSS WIGHT, C.L. HANSON, AND K.R. COOLEY

Abstract

Three models, CREAMS, SPAW, and ERHYM, were used to predict evapotranspiration (ET) from a sagebrush-grass range site in southwest Idaho. Model-predicted ET was compared with ET measured by a lysimeter and ET calculated with a water-balance equation using field-measured soil water and precipitation values. There was generally good agreement between the lysimeter and water-balance calculated ET and between these ET values and model-predicted ET. Maximum averaged daily ET rates were about 2.5 mm for April, May, and June with single day ET values from the lysimeter as high as 5.0 mm. Although the CREAMS predicted ET rates were generally higher than those predicted by SPAW and ERHYM or measured by the water-balanced method, all 3 models were functionally capable of simulating ET from sagebrush-grass range sites. ERHYM was the simplest of the 3 models to operate.

The sagebrush-grass ecosystem includes about 52.6 million ha in the western United States (U.S. Forest Service 1980). Although its productivity per unit area is low, the sagebrush ecosystem is a major resource in terms of livestock production, wildlife habitat, and as a watershed for onsite and downstream water resources. This ecosystem supplies an estimated 25 million animal unit months (AUM) of grazing for domestic livestock with a potential for 78 million AUMs with improved management and range condition (USDA-SEA-AR 1980).

Evapotranspiration (ET) is a major component of the soil water balance equation for semiarid rangelands. Branson et al. (1976) estimated that as much as 96% of the incoming precipitation was returned to the atmosphere as ET from such rangelands. Most estimates of ET from sagebrush-grass rangelands have been determined from field measurements of precipitation, soil water content, and runoff (Rawls et al. 1973, Sturgis 1979).

During the past decade, several water-balance, climate models have been developed that can be used to predict evapotranspiration from rangelands. Most of these models have been evaluated for the shortgrass and mixedgrass prairies (Innis 1978, Aase et al. 1973, Wight and Hanks 1981, de Jong and MacDonald 1975, Hanson 1976). Research on modeling ET from sagebrush-grasslands has been limited. Wight and Neff (1983) evaluated a water-balance, climate model in a sagebrush-grass community in southeastern Montana. Sonntag et al. (1982) developed an ecosystem model which included an ET component for a sagebrush-grass community in Nevada.

Accurate estimates of ET are essential in the development of effective hydrologic and plant growth models. This paper evaluates the ET predicting capability of 2 cropland models and 1 rangeland model for application to sagebrush-grass rangelands.

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Study Area

The study site was located in southwestern Idaho on the Reynolds Creek Experimental Watershed (Robins et al. 1965) on a nearly flat ridge top, at an elevation of 1,649 m. The soil is a Searla gravely loam of the loamy, skeletal, mixed, frigid family of the Calcic Argixerolls subgroup. Soil in the area averages about 100 cm in depth over a basalt bedrock. Annual precipitation averaged 34.9 cm for the 1962-1982 period.

The site is dominated by low sagebrush *(Artemisia arbuscula)* with sandberg bluegrass *(Poa sandbergii)* and bottlebrush squirreltail *(Sitanion hystrix)* comprising the major grass species. Basal cover for the past 11 years averaged 24, 26, 28, and 22% for live plants, litter, rock, and bare ground, respectively. Foliar cover averaged 45%.

Methods

Lysimetry

The study lysimeter was installed in 1968. It enclosed an undisturbed cylindrical soil core 152 cm in diameter and 122 cm deep. Changes in weight were measured by electrical transducers and were recorded with a digital recorder.

Soil Water Measurements

Soil water was monitored biweekly throughout most of the growing season by the neutron scatter method. Water content was measured in the 0 to 23, 23 to 46, 46 to 76, and 76 to 106-cm soil layers, respectively, in the lysimeter and an adjacent area. ET from the adjacent area was calculated as the sum of the change in soil water content and precipitation that occurred during soil measurement intervals. This method assumes no runoff. Observations of the area indicated that runoff is generally negligible. The soil water values at the beginning of the growing season were used to initialize model simulations each year.

Model-predicted ET

Three models were used to predict ET for the period 1976–1981: (1) SPAW (Soil-Plant-Air-Water) (Saxton et al. 1974); (2) CREAMS Chemicals, Runoff and Erosion from Agricultural Management Systems) (Knisel 1980); and (3) ERHYM (Ekalaka Rangeland Hydrology and Yield Model) (Wight and Neff 1983). The models were parameterized with soil and soil water data from the area adjacent to the lysimeter. Comparative model performance over the 6-year period was similar and only the results from 1977, 1978, and 1979, low, above average, and average production years, respectively, are discussed in detail. The SPAW and CREAMS ET

components were developed for cropland applications. The ERHYM ET component was originally developed for cropland application, but it has been modified for use on rangelands. The models were applied with essentially no "fitting" or calibration.

Each model uses a different procedure for calculating potential evapotranspiration (ET_p), potential transpiration (T_p), and potential soil evaporation (E_p) (Table 1). Actual transpiration (T) in each

Table 1. Methods of calculating potential evapotranspiration (ET_p), potential transpiration (T_p), and potential soil evaporation (E_p).

Model	ET_p	T_p	E_p*
SPAW	(E_{pan}) (PC)	(ET_p)(CF)(PF)	(ET_p)
CREAMS	Ritchie†	(ET_p)(LAI/3)‡	$(ET_p)(e^{-0.4LAI})$§
ERHYM	$(ET_{J-H})(K_c)$	(ET_p)(TRC)(RGC)	ET_p-T_p

PC = Pan coefficient
CF = Cover factor
PF = Phenology factor
LAI = Leaf area index
TRC = Transpiration coefficient = 0.0213 + 0.0162 (average site yield, lb/acre)$^{1/2}$
RGC = A relative growth curve that varies between 0.0 and 1.0
ET_{J-H} = Jensen-Haise calculated ET_p
*E_p is never allowed to exceed ET_p-T_p
†From Ritchie (1972).
‡For LAI values >3.0, T_p = ET_p
§For LAI values <1.70, E_p = 0.5 ET_p

model is controlled by available soil water as indicated in Figures 1a, 1b, and 1c. Water movement and root distribution vary among models. All models operated on a daily time scale.

SPAW

SPAW is a fairly comprehensive crop model that utilizes pan evaporation and a pan coefficient (PC) to calculate ET_p. Water added to the soil moves through the profile along hydraulic gradiants. Water in excess of field capacity is drained through the soil as percolate. T_p is controlled by a plant cover factor (CF), a phenology factor (PF), and available by soil water (Fig. 1a). Soil evaporation is represented by an inclusion of a separate thin (1.3 cm) upper boundary layer (evaporation layer of soil in the soil profile). Water is evaporated from this layer and is limited only by ET_p and water content. Water content of this layer varies between air dry and field capacity and water is replenished by upward movement from the second soil layer driven by a Darcian type equation. The SPAWET model is the most process oriented of the 3 models evaluated.

CREAMS

The hydrologic component of CREAMS utilizes an ET routine developed by Ritchie (1972). ET_p is calculated from solar radiation, average air temperature, albedo, a psychometric constant, and a leaf area index. T equals T_p until 75% of the available water is removed (Fig. 1b). Transpiration demand is distributed down through the profile based on a root distribution that is described by an exponential function. Soil evaporation is calculated by the two-stage drying process and is limited to the top 15-cm layer of soil profile.

ERHYM

This model calculates ET_p as the product of the Jensen-Haise calculated ET_p (alfalfa as the reference crop) and a crop coefficient (K_c) (Jensen and Haise 1963). In addition to water content (Fig. 1c), transpiration from specific soil layers is controlled by the product of a transpiration coefficient, soil temperature, and a root density factor. The transpiration coefficient represents the portion of ET which can be T at peak standing crop. Soil temperatures are obtained from a soil temperature simulation routine. The root density factor is a recent modification of the original model which controls rate of water uptake based on the density of roots in each soil layer. Soil evaporation is limited to the top 30 cm of the soil profile and utilizes a one-stage drying process.

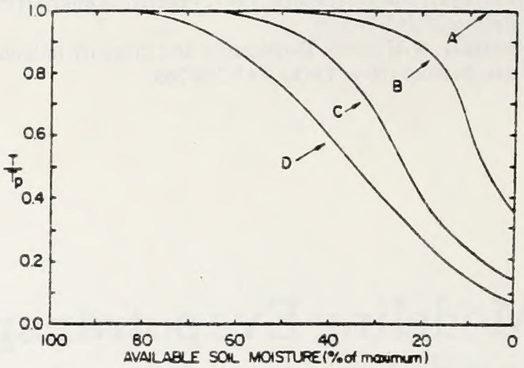

Fig. 1a. *The relationship between T/T_p and available soil water as used in SPAW where curves A, B, C, and D represent different levels of atmospheric demand (potential ET). (From Saxton and McGuiness 1982.)*

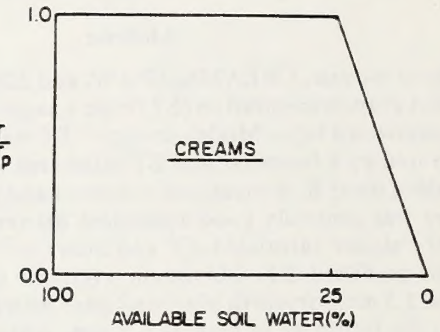

Fig. 1b. *The relationship between T/T_p and soil water as used in CREAMS.*

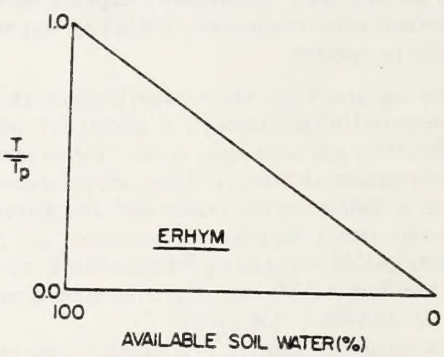

Fig. 1c. *The relationship between T/T_p and available soil water as used in ERHYM.*

Results and Discussion

A typical set of growing season ET_p curves as calculated by the 3 models is presented in Figure 2. The CREAMS and SPAW ET_p are

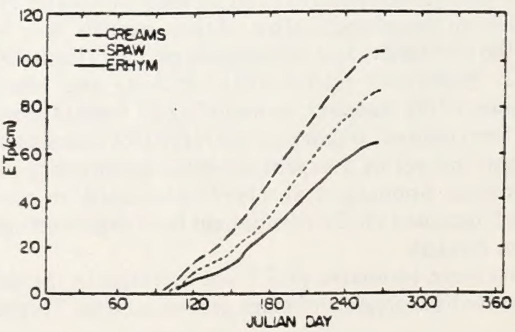

Fig. 2. *Cumulative potential evapotranspiration as calculated by SPAW, CREAMS, and ERHYM. Reynolds Creek, 1977.*

Table 2. Model-predicted and field-measured evapotranspiration, beginning soil water content, and monthly precipitation for 3 growing seasons at the Reynolds Creek study site.

	April	May	June	July	August	September	BSW†
	(mm/day)						(mm)
1977							
Lysimeter	nd*	1.98	2.67	1.59	0.96	1.14	18
Water balance	0.34	1.42	1.63	1.28	0.32	0.92	2
SPAW	0.62	1.65	1.67	0.48	0.35	0.56	2
CREAMS	1.46	2.80	2.01	0.39	0.81	0.22	2
ERHYM	0.46	1.32	2.24	0.70	0.27	0.28	2
Precipitation (mm/month)	2	63	47	10	15	14	
1978							
Lysimeter	2.40	1.77	2.53	1.15	0.88	1.11	119
Water balance	2.57	1.63	2.15	1.14	0.73	0.67	86
SPAW	2.32	3.14	1.58	0.91	0.41	0.40	86
CREAMS	2.82	3.01	1.62	0.67	0.48	0.75	86
ERHYM	1.01	1.83	2.57	1.13	0.62	0.58	86
Precipitation	84	18	17	12	12	22	
1979							
Lysimeter	1.35	2.45	2.41	0.69	1.25	0.55	129
Water balance	0.97	1.39	1.37	0.82	1.04	0.80	54
SPAW	2.16	1.65	0.52	0.16	0.76	0.13	54
CREAMS	2.09	2.43	0.89	0.27	1.09	0.58	54
ERHYM	0.89	1.83	1.45	0.32	1.09	0.57	54
Precipitation	20	28	11	5	49	2	

*nd = no data available.
†Amount of available plant soil water in the root zone at the beginning of the growing season (approximately April 1).

considerably higher than the ERHYM ET_p. The Jensen-Haise based ET_p in ERHYM is calculated by an empirical equation which was developed using alfalfa as a reference crop. For this study, a crop coefficient (K_c) of 0.85 was used to convert the Jensen-Haise ET_p to a rangeland ET_p. This K_c value was determined using lysimeter data from a mixed prairie grassland in eastern Montana (Wight and Hanks 1981).

Alfalfa requires relatively warm weather before it begins growth in the spring, thus the ET_p based on the Jensen-Haise method is limited by cool weather and this is reflected by the low values calculated for the early spring. Similar limitations would occur during the fall and winter periods.

In addition to solar radiation and temperature, CREAMS uses an albedo input in calculating potential evaporation. An average albedo of 0.15 for the study site area was reported by Belt (unpublished data 1972). Dirmhirn and Belt (1971) reported an albedo of 0.13 for a similar site in southeastern Idaho. These albedo values represented midday measurements and are somewhat lower than would be expected for daily averages. The low albedo helps account for the high ET_p values calculated by CREAMS.

Average daily ET rates for each month as measured by the lysimeter and water-balance methods and the model-predicted ET values are presented in Table 2. The good agreement between lysimeter and water-balanced measured ET values supports the reliability of the water-balance ET data. The major differences between the 2 methods were due to differences in soil water contents at the beginning of the growing season. These differences were probably due to seepage of rain water along the inside walls of the lysimeter and/or the restriction to drainage through the lysimeter. Maximum averaged daily ET rates were about 2.5 mm/day for April, May, and June. The availability of soil water significantly limited ET during the remainder of the growing season. ET values from the lysimeter on days following significant precipitation reached maximum values of 4.5 to 5.00 mm in the summer months.

For most of the growing season, the SPAW, ERHYM, and lysimeter cumulative ET curves were parallel, indicating good agreement on daily ET rates (Fig. 3). The CREAMS ET values were a little higher than the values determined by the other methods, but the seasonal dynamics were very similar. The high ET rates measured by the lysimeter at the beginning of the growing season (Julian days 124 to 128) indicate a weakness of the models in

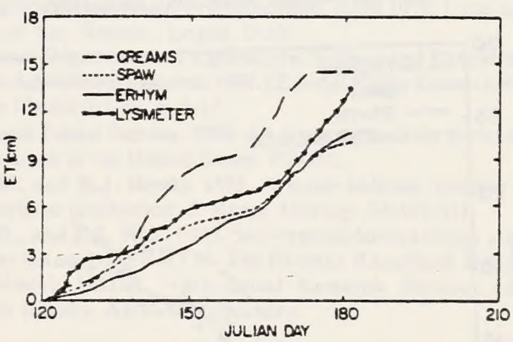

Fig. 3. *Model-predicted and lysimeter-measured evapotranspiration. Reynolds Creek, 1977.*

accounting for ET under some weather conditions. Wet cool weather prevailed during the period Julian day 121 to 131 with numerous precipitation events totaling about 5 cm and mean daily temperatures averaging about 6° C. During this period both the lysimeter and the evaporation pan measured about 3 cm of ET and evaporation, respectively. The model-predicted values were significantly lower than the lysimeter-measured values. Apparently, the models underpredicted the evaporation from an essentially free water surface that occurred during this period. Also, the model ET_p may have been unrealistically low, possibly due to very low temperatures.

Comparisons of model-predicted and water-balance-calculated ET for the area adjacent to the lysimeter are presented in Figures 4a, 4b, and 4c. For the average and below-average production years, CREAMS predicted higher ET than did ERHYM or SPAW,

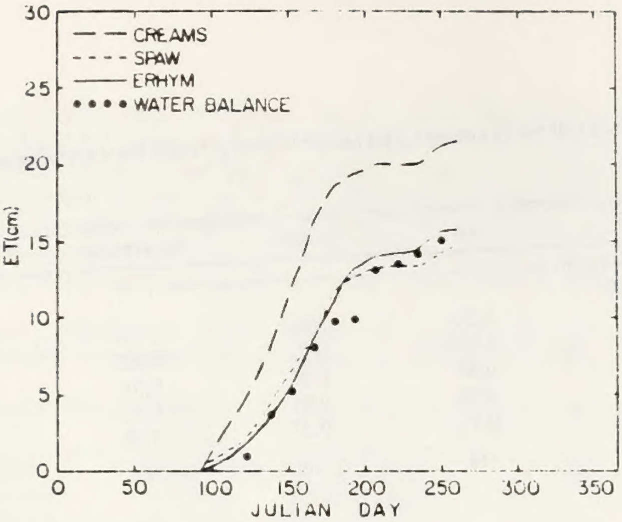

Fig. 4a. *Seasonal evapotranspiration as determined by the models and water-balance method. Reynolds Creek, 1977.*

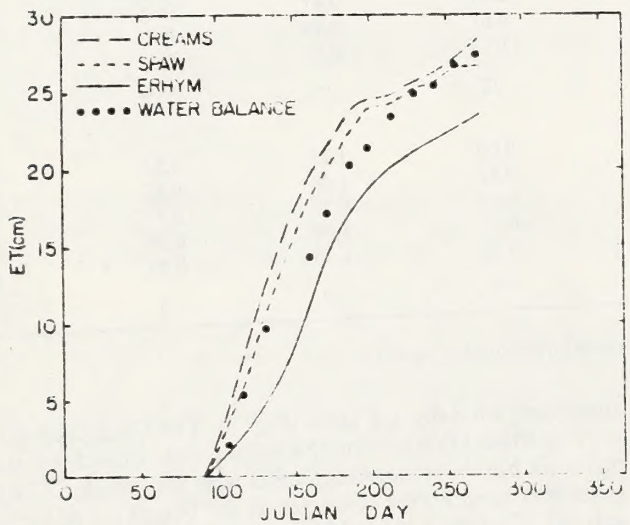

Fig. 4b. *Seasonal evapotranspiration as determined by the models and water-balance method. Reynolds Creek, 1979.*

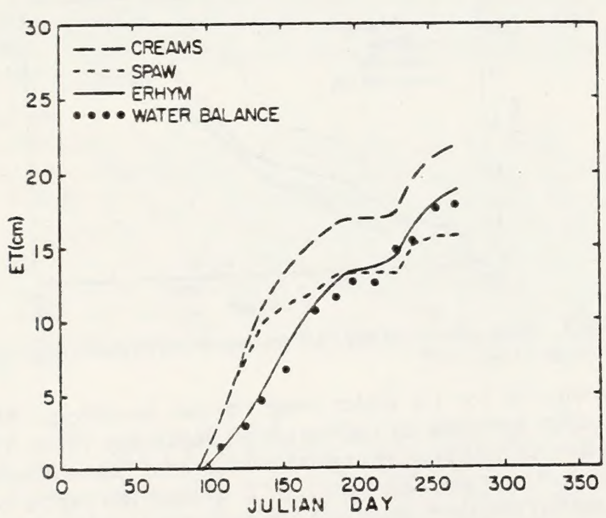

Fig. 4c. *Seasonal evapotranspiration as determined by the models and water-balance method. Reynolds Creek, 1978.*

which were in general agreement with the field-measured values. For the above-average production year (1978), both CREAMS- and SPAW-predicted ET were in good agreement with the field-measured ET, while ERHYM-predicted ET was slightly lower than the field-measured ET. Differences in ET rates were most pronounced early in the growing season when soil water was most plentiful.

The CREAMS ET routine allows up to 75% of the available water to be removed before water content limits T (Fig. 1b). This is reflected by a higher percentage of ET attributed to T by the CREAMS model than by the other 2 models (Table 3). By allowing only 30% of the available soil water to be removed before water content limits T as suggested by de Jong and MacDonald (1975) for native grass, ET was reduced 10% during the first 60 days of the growing season, making it more in line with the other models and field-measured values. Such modifications are simple to make and should be considered before applying CREAMS type ET routines to rangeland sites.

The models partitioned ET into E and T somewhat differently (Table 3). The SPAW model predicted little or no T in August and September, while CREAMS predicted relatively high T rates during those 2 months. These extreme values probably reflect some of the difficulties in the direct application of cropland ET models to rangeland plant communities. Quantification of crop-developed parameters such as leaf area index and phenological, or plant cover curves for rangeland conditions would realistically take a little calibration and tuning.

Model-predicted ET was regressed on the water balance-calculated ET for the periods that coincided with the soil water measurements (approximately 2-week intervals) and the coefficients of determination (r^2 values) were calculated (Table 4). The slopes and y-intercepts of the regression lines indicate that SPAW and ERHYM simulated ET a little better than did CREAMS. However, with some adjustments of the ET controlling parameters, all models may have been equal in performance.

As would be expected, the model-predicted and field-measured ET rates all approached zero at the end of the season, indicating that all available water had been evapotranspired. For semiarid rangeland, this is normally the case and is an advantage in long-term simulations in that the models are "zeroed out" each year, preventing cumulative errors in soil water accounting.

Conclusions

All 3 models appeared to be functionally capable of simulating ET from sagebrush-grass rangelands. Major differences in the models' performance were generally at the beginning of the growing season and during the below-average and average production years. Performance of the 3 models probably could have been improved by tuning or calibration through the adjustment of soil and vegetation parameters. All vegetation parameters were based on average conditions and were not sensitive to the annual variations of a native plant community. Of the 3 models tested, SPAW and ERHYM were best able to simulate ET from the study site. Compared to SPAW and CREAMS, ERHYM is simpler to operate and the required input data were more readily available.

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Table 3. Percent of model-predicted evapotranspiration attributed to transpiration at Reynolds Creek.

	April	May	June	July	August	September	Seasonal
1977							
SPAW	72	36	47	29	0	0	37
CREAMS	54	60	43	23	31	38	50
ERHYM	29	45	34	9	9	0	32
1978							
SPAW	34	67	73	51	3	0	51
CREAMS	36	68	73	45	29	38	53
ERHYM	14	66	59	57	36	16	51
1979							
SPAW	50	67	27	0	0	0	43
CREAMS	37	73	70	48	28	38	52
ERHYM	47	62	44	52	26	3	44
Mean							
SPAW	52	57	49	27	3	0	44
CREAMS	42	67	62	39	29	38	52
ERHYM	30	58	46	39	24	6	42

Table 4. Means, slopes, Y-intercepts, and r^2 values for the regressions of model-predicted evapotranspiration on water-balance ET measured at bi-weekly intervals* during the growing season.

	Water-Balance				SPAW				CREAMS				ERHYM			
	1977	1978	1979	Mean	1977	1978	1979	Mean	1977	1978	1979	Mean	1977	1978	1979	Mean
Mean (mm)	3.32	7.09	3.92	4.78	3.56	7.50	4.32	5.12	5.64	7.93	5.45	6.34	3.62	5.84	4.13	4.53
Slope	—	—	—	—	0.90	0.99	0.73	0.87	1.26	0.99	1.07	1.10	1.03	0.93	1.04	1.00
Y-intercept (mm)	—	—	—	—	0.57	0.51	1.47	0.85	1.44	0.90	1.23	1.19	.19	−0.74	0.07	0.33
r^2	—	—	—	—	0.96	0.98	0.88	0.94	0.92	0.97	0.94	0.94	0.97	0.98	0.99	0.98

*N for 1977, 1978, and 1979 was 13, 12, and 13, respectively.

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data as input for a rainfall-runoff model. The stochastic generation of rainfall data is a usefull tool that may be used to extend limited rainfall records. Such extended rainfall records, used in conjunction with a suitable hydrological model could provide valuable information regarding the long term water resource potential of a watershed.

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Validation of SWRRB -- A Simulator for Water Resources in Rural Basins

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Introduction

A model called SWRRB (Simulator for Water Resources in Rural Basins) was developed for simulating hydrologic and related processes in rural basins. The SWRRB model was developed by modifying the CREAMS daily rainfall hydrology model (Knisel, 1980; Williams and Nicks, 1982) for application to large, complex, rural basins. The major changes involved were (a) a weather generator was added; (b) the model was expanded to allow simultaneous computations on several sub-basins; (c) a return flow component was added; (d) a reservoir component was added; and (e) a flood routing component was added.

The three major components of SWRRB are weather, hydrology, and sedimentation. Processes considered include surface runoff, return flow, percolation, evapotranspiration, transmission losses, pond and reservoir storage, sedimentation, and crop growth. A weather generator (Nicks, 1974) allows precipitation and temperature to be simulated when measured data is unavailable. Surface runoff is predicted using the SCS curve number (USDA, 1972) as a function of daily soil moisture content. Evapotranspiration is estimated using Ritchie's ET model (Ritchie, 1972). SWRRB also simulates sediment yields using the Modified Universal Soil Loss Equation (MUSLE) (Williams and Berndt, 1977) and a sediment routing model.

Since SWRRB operates on a daily time step, computer cost for overnight turn around is only about $0.15 per year of simulation (for a basin with four sub-basins) on an AMDAHL 470 computer. The model can be run on a variety of minicomputers since storage requirements are only 124K bytes. A user manual and interactive data entry system are available for user convenience.

The objective in SWRRB model development was to predict the effect of management decisions on water and sediment yields with reasonable accuracy for ungaged rural basins throughout the U.S. Tests on 12 widely varying watersheds throughout the U.S. have been completed to validate the model.

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Description of Watersheds

Twelve watersheds from 8 Agricultural Research Service (ARS) watershed locations were chosen to test SWRRB. These locations represent a wide range of climate, soil, land use, and management conditions. Table 1 contains a list and brief description of the watersheds used in the validation. Average land use during the validation period and the number of sub-basins used in SWRRB are given.

Table 1. Watersheds for SWRRB validation.

Location	ARS watershed	Area (km^2)	No. of sub-basins	Average land use
Chickasha, OK	552	538.1	4	66% pasture & range, 18% crop, 16% misc.
Riesel, TX	6	17.7	1	65% crop, 22% pasture, 13% grass
Coshocton, OH	994	70.8	1	55% grass, 28% forest, 17% crop
Coshocton, OH	97	18.5	1	50% grass, 30% forest, 20% crop
Tifton, GA	B	334.0	2	42% forest, 38% crop, 20% pasture
Tifton, GA	K	16.7	2	56% forest, 30% crop, 14% pasture
Boise, ID	1	233.6	3	95% rangeland, 2% forest, 3% crop
Oxford, MS	34	303.5	5	55% pasture, 23% crop, 22% forest
N. Danville, VT	5	111.2	3	67% forest, 20% crop, 13% grass
Tombstone, AZ	1	149.2	5	65% desert shrub, 35% grass
Tombstone, AZ	3	9.0	5	65% desert shrub, 35% grass

A brief description of important hydrologic processes and watershed characteristics for each location follows. The watershed at Chickasha, OK, has a wide range of soils and land uses. Nineteen reservoirs were built within the basin by the SCS between 1969 and 1971. Nearly 20% of the watershed flows into ponds. The soils at Riesel, TX, have a high clay content and high shrink/swell potential. The surface/subsurface flow ratio is approximately 9.5. At Coshocton, OH, the soils also have a high shrink/swell potential and much of the basin is underlain by shallow limestone. The surface/subsurface flow ratio is approximately 0.20. The Little River watershed at Tifton, GA, has a surface/subsurface ratio of 0.45. The basin consists of upland and swamp-alluvial areas. The upland soils are sandy with rapid permeability while the swamp-alluvial soils have very low permeability. The swamp-alluvium acts as a filter for sediment from the uplands. Reynolds Creek watershed near Boise, ID, contains 95% rangeland. There are large differences in precipitation, temperature, and elevation within the basin with snowfall and snow melt being dominant hydrologic processes. Fifteen percent of Pidgeon Roost Creek Watershed near Oxford, MS, flows into desilting ponds. The rolling topography is covered by crops, pasture, and forest. Precipitation, temperature, and elevation vary widely within the watershed near N. Danville, VT. Snowfall and snowmelt are important processes in this highly forested basin. At Walnut Gulch watershed near Tombstone, AZ, rainfall is infrequent and isolated. Limited runoff occurs during the summer and early fall months. Channel transmission losses are high.

Results and Discussion

Average annual basin values from SWRRB validation runs are given in Table 2 for the major hydrologic processes and sedimentation for each watershed. The wide range in climatic and hydrologic variables is evident in Table 2.

Table 2. Hydrologic and sedimentation results from the SWRRB validation runs.

ARS watershed	Rainfall	Surface runoff	Subsurface runoff	ET	Percolate	Transmission losses	Sediment yield
	(mm)						t/ha
OK-522	720	20	23	551	156	4.1	3.7
TX-G	890	152	16	721	7.9	1.6	1.6
OH-994	914	67	271	593	4.3	0.3	2.5
OH-97	912	24	260	638	16.2	0.3	3.5
GA-B	1157	127	265	772	9	1.3	.10
GA-K	1150	121	320	722	10	1.2	.12
ID-1	446	40	33	317	56	0.7	.23
MS-34	1349	247	222	853	41	4.2	8.4
VT-5	1157	340	206	609	1.4	0.5	3.6
AZ-1	335	7.4	0	315	14	2.6	.11
AZ-3	319	6.1	0	300	15	1.6	.14

Table 3 shows the results of measured and simulated annual water yields. It is important for simulation models to produce frequency distributions that are similar to measured frequency distributions. Close agreement between means and standard deviations indicates that the frequency distributions are similar. Generally, simulated values compare very well with measured values. Although the average annual percent error can be greatly influenced by only a few years, it can be

a good indication of annual accuracy. The overall error for all watersheds tested is less than 20%.

Table 3. Comparison of measured and SWRRB simulated annual water yields.

ARS watershed	Period of record	Measured mean	Predicted mean	Measured st. dev.	Predicted st. dev.	Average % error
		(mm)				
OK-522	62-81	48	49	27	25	31
TX-G	61-82	169	149	129	88	30
OH-994	42-65	334	338	107	110	13
OH-97	44-53	296	284	95	94	10
GA-B	68-80	357	390	56	64	18
GA-K	72-80	424	437	68	66	15
ID-1	67-80	75	72	40	31	25
MS-34	64-73	445	452	161	161	16
VT-5	60-73	556	521	133	146	11

It is important for SWRRB to accurately predict monthly water and sediment yields. The shorter time span allows examination of accuracy for seasonal phenomena such as climate, crop growth, residue cover, etc. The results of measured and simulated monthly water yields are shown in Table 4. Slope and R^2 values near unity indicate a close relationship between measured and simulated monthly water yields. Monthly standard deviations are given in Table 4 to indicate the agreement in monthly frequency distributions. In general, the simulated monthly water yields compare well with measured monthly values.

Table 4. Comparison of measured and SWRRB simulated monthly water yields.

ARS watershed	Measured st. dev.	Predicted st. dev.	R^2	Slope
	(mm)			
OK-522	4.9	5.5	0.60	0.70
TX-G	27	20	0.78	1.14
OH-994	33	31	0.72	0.89
OH-97	32	23	0.61	1.06
GA-B	38	31	0.70	1.01
GA-K	41	32	0.61	1.00
ID-1	8.4	8.2	0.69	0.85
MS-34	38	43	0.82	0.79
VT-5	46	54	0.35	0.51

The annual and monthly results of measured and simulated sediment yields are shown in Table 5. Only five of the selected watersheds had sediment data available. Means, standard deviations and R^2 values are given to indicate agreement in frequency distributions. The simulated sediment yields compare reasonably well with measured sediment yields considering the wide range of conditions.

Table 5. Comparison of measured and SWRRB simulated sediment yields.

ARS watershed	Period of record	Annual				Monthly		
		Meas. mean	Pred. mean	Meas. st.dev.	Pred. st.dev.	Meas. st.dev.	Pred. st.dev.	R^2
		(t/ha)				(t/ha)		
OK-522	64-81	3.8	3.4	2.6	2.7	.75	.85	.78
TX-G	61-82	1.5	1.8	1.4	1.1	.32	.30	.75
GA-K	79-80	.05	.08	.005	.01	.006	.01	.51
ID-1	75-80	.26	.23	.15	.18	.05	.06	.17
MS-34	64-75	13.6	8.4	9.0	3.3	2.0	1.0	.55

During 1969-1971, 19 SCS flood control structures were constructed to control runoff from 17% of the Little Washita basin near Chickasha, OK. Results from SWRRB simulations showed that the structures did not significantly deplete water yield to downstream reservoirs, but they did trap 36% of the sediment that would have been deposited downstream (Williams et al., 1985). This demonstrates the model's usefulness in evaluating the effects of flood control structures.

Sediment deposition is extremely high in the swamp-alluvium at Tifton, GA. The simulated average annual sub-basin yield for watershed K is 1.15 t/ha while the sediment yield at the basin outlet is only 0.08 t/ha. The measured average annual sediment yield at the basin outlet is 0.05 t/ha. According to Shirmohammadi et al. (1984), surface/subsurface flow ratios for watersheds B and K are 0.47 and 0.45, respectively. This compares closely with SWRRB simulated results.

Sediment yields from the Reynolds Creek watershed at Boise, ID, are very low. This is due in part to rock cover on the steep slopes which is not accounted for by MUSLE. Consequently, SWRRB sediment estimates are high. Simanton et al. (1984) incorporated rock cover into the USLE by adjusting the C factor. The C factor was adjusted for rock cover in SWRRB and predicted sediment yields were reduced to an acceptable level.

Gully erosion is a major source of sediment from the Pidgeon Roost Creek watershed at Oxford, MS. Predicted sediment yields are low because MUSLE does not account for gully erosion. Assuming gully

erosion explains for the difference in predicted and measured sediment yields, it would account for 38% of the total sediment yield.

Monthly slope and R^2 values are low for the basin at N. Danville, VT. This was apparently caused by the lack of measured temperature data (temperature was generated). In areas where snow is important, measured temperature data is critical in obtaining a good agreement between monthly measured and simulated runoff. The annual statistics are in good agreement.

Although average annual transmission losses seem low, they can be extremely high for individual events at Tombstone, AZ. For example, in one simulation run the runoff for August was 43 mm and the transmission losses for that month were 15 mm.

Another test of the model was the simulation of basin rainfall as well as water yield at Tombstone, AZ. Watersheds 1 and 3 had 15 and 17 years of available runoff data, respectively. Ten 15-year simulations were run for watershed 1 and ten 17-year simulations for watershed 3. Table 6 shows the results of the simulation runs. The means of the simulations were compared statistically with the observed data. The mean values of rainfall, runoff, and runoff standard deviation for both watersheds are not significantly different from the measured values at the $t_{.05}$ level. The simulated average annual rainfall for the period was higher than the observed for both watersheds because some of the rainfall generator parameters were not available for the watersheds and were taken from other locations.

Table 6. Comparison of annual rainfall, runoff, and standard deviation of runoff at Tombstone, AZ.

Run	Watershed AZ-1			Watershed AZ-3		
	Rainfall	Water yield	Water yield st. dev.	Rainfall	Water yield	Water yield st. dev.
	(mm)					
1	323	4.71	5.84	306	4.75	9.06
2	339	4.66	5.76	307	5.30	12.13
3	344	4.50	9.35	326	5.92	5.97
4	335	3.34	4.42	347	4.38	5.69
5	350	5.61	8.98	336	3.39	4.85
6	358	5.14	6.42	322	3.04	4.62
7	342	4.84	5.02	326	3.41	5.14
8	325	4.71	8.70	320	5.36	6.46
9	318	4.53	9.19	298	4.38	5.33
10	317	5.54	10.55	299	6.42	13.56
Simu.	335	4.76	7.42	319	4.50	7.28
Obsr.	302	4.80	3.67	290	4.40	5.62
Diff.	33	0.18	3.88	29	0.10	1.66

Table 7 shows the monthly results of the simulation runs. The results show that SWRRB can realistically simulate monthly water yields when rainfall is generated.

Table 7. Comparison of measured and SWRRB simulated monthly water yields at Tombstone, AZ.

Run	J	F	M	A	M	J	J	A	S	O	N	D
Watershed AZ-1												
1	.17	.10	.01	0	0	0	.12	2.80	.47	.87	0	0
2	0	0	0	0	0	0	.29	2.38	1.97	.02	04	.01
3	0	.19	.05	0	0	0	.36	2.47	1.71	.02	0	.05
4	.03	0	.04	0	0	0	.91	4.06	.06	.05	0	0
5	.08	0	.01	0	0	0	.79	1.88	2.87	.01	0	0
6	.06	0	0	0	0	0	1.79	.59	.78	.11	0	.1
7	.04	0	.12	0	.10	.01	.52	1.84	1.67	.22	0	0
8	0	.01	0	0	0	0	.62	2.59	1.14	.09	0	.22
9	.08	0	0	0	0	0	.42	3.29	.83	0	.04	.07
10	.06	0	.04	0	0	.02	1.6	3.38	.40	.04	0	0
Ave.	.05	.03	.02	0	.01	0	0.74	2.52	1.19	.14	.01	.04
Meas.	0	0	0	0	0	.02	1.28	2.29	.92	0	0	0
Watershed AZ-3												
1	0	0	0	0	0	0	.60	1.85	2.919	.05	0	.05
2	.04	0	0	0	0	0	.44	2.19	2.61	.01	0	.02
3	.01	.23	0	0	0	0	.54	3.45	1.56	.01	0	.11
4	.05	0	.01	0	0	0	1.24	2.72	.16	.06	0	.15
5	.08	0	.01	0	0	0	.72	.71	1.81	.04	0	.01
6	.07	0	.07	0	0	0	1.38	.75	.67	.07	0	.04
7	.04	0	.04	0	0	.18	.79	1.36	.65	.35	0	0
8	.02	0	0	0	0	0	.58	3.44	1.10	.04	0	.19
9	.08	0	0	0	0	0	.79	2.82	.55	0	.3	.10
10	.03	0	.13	0	0	.02	1.75	1.62	2.72	.15	0	0
Ave.	.04	.02	.03	0	0	.02	.88	2.09	1.40	.08	.03	.07
Meas.	0	0	0	0	0	.15	.66	2.67	.62	.03	0	0

Summary and Conclusions

The SWRRB model was developed for simulating water and sediment yields from large ungaged rural basins throughout the U.S. Because of the water and sediment routing components and because each sub-basin can use a different rain gage, SWRRB is not limited by drainage area. User convenience is enhanced by readily available input data, interactive data entry, and a user manual. The model is computationally efficient and is running on a few popular minicomputers.

SWRRB has been tested on twelve large watersheds from 8 ARS locations throughout the U.S. The results show SWRRB can realistically simulate water and sediment yields under a wide range of soils, climate, land use, topography, and management. Also, the model's usefulness in evaluating the effects of flood control structures was demonstrated at Chickasha, OK (Williams et al., 1985). SWRRB should provide a versatile and convenient tool for use in planning and designing water resources projects.

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URBAN HYDROLOGY FOR SMALL WATERSHEDS (REVISED 1985)

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Abstract

Urban Hydrology for Small Watersheds(3), Technical Release 55, was first issued by the Soil Conservation Service in January 1975. It is a guide for SCS field personnel for estimating hydraulic and hydrologic parameters used in computing runoff volumes and peak rates of discharge in urban and urbanizing areas. SCS has revised TR-55 to incorporate results of recent research and other changes based on experience in using and helping others use the original edition. Changes and additions have been made throughout the document; only the major ones are covered in this paper. The authors assume that the reader is familiar with the original TR-55.

Introduction

Urban Hydrology for Small Watersheds(3), Technical Release 55, (TR-55) presents simplified procedures for the estimation of hydraulic and hydrologic parameters used in the development of runoff volume and peak rates of discharge in small urban and urbanizing areas. It was originally issued in January 1975 because Soil Conservation Service (SCS) field personnel needed hydrology procedures to use in urban and urbanizing areas. "SCS technicians and engineers were being inundated with requests from soil and water conservation districts, cities, counties, and others to verify and approve erosion and storm water management plans prepared by developers and their consultants. The SCS staff needed a direct approach with a simple set of procedures that give a reproducible result acceptable to both developers and regulators"(2). TR-55 incorporates methods that follow, as much as possible, existing SCS methods developed for use in rural areas.

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BASIN TRY... TEST FILE USING LOWER SHEEP WEATHER DATA 4/10/86
1 BASIN, 4 SOIL LAYERS, DAILY PRINTOUT
(SWRBMAIL)

NO YRS = 1
BASIN AREA = 538.200 KM**2
AVE A RAINFALL/AVE A FOR GAGE = 1.000
TP-40 RAINFALL AMOUNTS (10 YR FREQ) FOR DUR
0.5 H = 56.00MM
6H=108.00MM
NO YRS RECORD MAX .5H RAIN = 8.0
SED RT COEF
AGGRAATION = .10000E-01
DEGRAATION = .27880E-03
LATITUDE = 35.10DEG
BASIN LAG TIME= 30.00D

GENERATOR CYCLES = 0

GENERATOR SEEDS

9	98	915	92
135	28	203	85
43	54	619	33
645	9	948	65
885	41	696	62
51	78	648	0
227	57	929	37
205	90	215	31
320	73	631	49

BASIN TRY... TEST FILE USING LOWER SHEEP WEATHER DATA 4/10/86
1 BASIN, 4 SOIL LAYERS, DAILY PRINTOUT
(SWRBMAIL)
CLIMATE DATA

RAINFALL DATA USED IN THIS RUN ARE:
MEASURED MULTIPLE RAINGAGES

TEMPERATURE DATA USED IN THIS RUN ARE;
SIMULATED SINGLE TEMP

-MO RAIN PROB--		-MO STATS FOR DAILY RAIN-		
W/D	W/W	MEAN	ST DV	SKW CF
.078	.300	5.560	7.720	1.127
.120	.333	5.490	6.810	.860
.132	.304	8.360	10.080	1.220
.159	.417	9.170	11.380	.730
.177	.427	14.350	21.260	2.342
.224	.378	11.280	15.700	2.953
.122	.346	10.690	13.660	1.492
.178	.361	9.910	15.010	2.809
.197	.330	16.050	27.480	3.861
.124	.393	9.520	10.970	.380
.124	.342	8.790	13.820	2.720
.125	.341	4.490	6.960	2.629

	R5MX	TMX	TMN	RA	CVT	RAIN	DAYP	ALPH
JAN	8.10	8.94	-3.48	219.50	.34	17.38	3.13	.40
FEB	11.40	11.60	-1.78	290.00	.24	24.30	4.43	.49
MAR	28.40	16.90	3.23	370.30	.22	41.28	4.94	.45

APR	25.10	23.40	9.77	453.10	.15	59.03	6.44	.53
MAY	42.40	27.00	14.01	511.10	.12	104.93	7.31	.45
JUN	55.40	31.60	19.30	553.50	.07	89.54	7.94	.57
JUL	39.10	34.30	21.70	544.30	.06	52.11	4.87	.59
AUG	28.40	32.80	20.30	501.30	.06	66.86	6.75	.51
SEP	31.70	28.40	16.90	392.50	.11	109.34	6.81	.31
OCT	22.90	23.60	9.82	332.00	.14	49.98	5.25	.47
NOV	26.70	16.50	3.58	237.20	.19	41.75	4.75	.42
DEC	13.50	10.80	-1.46	197.40	.27	22.15	4.93	.56
YR	25.96	22.15	9.32	383.52	.16	678.66	67.55	.48

BASIN TRY... TEST FILE USING LOWER SHEEP WEATHER DATA 4/10/86
1 BASIN, 4 SOIL LAYERS, DAILY PRINTOUT
(SWRBMAIL)
SUB-BASIN DATA

SUB-BASIN AREA/BASIN AREA
.297

POND CATCHMENT AREA FRACTION
.195

POND SURFACE AREA(HA)
141.10

MAX POND STORAGE(MM)
24.0

INTIAL POND STORAGE(MM)
20.0

INITIAL SED CONC IN PONDS(PPM)
402.

NORMAL SED CONC IN PONDS(PPM)
400.

SAT CONDUCTIVITY FOR POND AND RESERVOIR BOTTOMS(MM/H)
.08

RESERVOIR CATCHMENT AREA FRACTION
.200

RESERVOIR SURFACE AREA AT EMERGENCY SPILLWAY(HA)
258.57

RESERVOIR STORAGE AT EMERGENCY SPILLWAY(MM)
89.0

RESERVOIR SURFACE AREA AT PRINCIPAL SPILLWAY(HA)
74.66

RESERVOIR STORAGE AT PRINCIPAL SPILLWAY(MM)
29.1

INITIAL RESERVOIR STORAGE(MM)
.0

AVE RESERVOIR RELEASE RATES(M**3/S/KM**2)
.13700

```
   INITIAL SED CONC IN RESERVOIRS(PPM)
  0.

   NORMAL SED CONC IN RESERVOIRS(PPM)
 250.

   SAT CONDUCTIVITY OF RESERVOIR BOTTOMS (MM/H)
  .08

   2 COND CN
 75.0

   SOIL ALBEDO
  .15

   WATER CONTENT OF SNOW COVER (MM)
  .0

   MAIN CHANNEL LENGTH (KM)
21.90      30.20

   CHANNEL SLOPE(M/M)
.0038      .0028

   HYDRAULIC CONDUCTIVITY OF CHANNEL ALLUVIUM (MM/H)
10.000    10.000

   CHANNEL N VALUE
 .050       .050

   OVERLAND FLOW N VALUE
 .050       .050

   TRAVEL TIME FROM SUB-BASIN OUTLETS TO BASIN OUTLET(H)
 6.50

   TIME OF CONCENTRATION FOR SUB-BASINS(H)
 3.29       4.30

   RET FLO SED CONC (PPM)
 750.

   RET FLO TRAVEL TIME(D)
30.000

   SLOPE LENGTH(M)
  55.

   SLOPE STEEPENESS(M/M)
.0800

   SOIL ERODIBILITY FACTORS (K)
  .31

   EROSION CONTROL PRACTICE FACTORS(P)
 1.00

   SLOPE LENGTH AND STEEPNESS FACTORS(LS)
 1.42
```

BASIN TRY... TEST FILE USING LOWER SHEEP WEATHER DATA 4/10/86
1 BASIN, 4 SOIL LAYERS, DAILY PRINTOUT
(SWRBMAIL)
SOILS DATA

ST NO	LAYER DEPTH (MM)	POROSITY (MM/MM)	15 BAR SW (MM/MM)	.3 BAR SW (MM/MM)	AVAIL W ST (MM)	INITIAL W ST (MM)	SAT COND (MM/H)
1	10.0	.47	.09	.28	1.9	.5	16.C
2	150.0	.47	.09	.28	26.6	6.8	16.C
3	510.0	.42	.14	.33	68.4	17.4	15.C
4	840.0	.40	.22	.41	62.7	16.0	12.C
TOTALS					159.6	40.6	

MEDIAN SED. PART SIZE = 18.36

INITIAL COMPOSITE ST = 12.1 MM

BASIN TRY... TEST FILE USING LOWER SHEEP WEATHER DATA 4/10/86
1 BASIN, 4 SOIL LAYERS, DAILY PRINTOUT
(SWRBMAIL)

CROP DATA

SUB-BASIN
1 PLANTING DATE = 3/15
HARVEST DATE = 9/15
TILLAGE OPERATION =FALL PLOW
POT HEAT UNITS = 4136. C
AVE C FACTOR = .200
MAX LAI = 3.0

BASIN TRY... TEST FILE USING LOWER SHEEP WEATHER DATA 4/10/86
1 BASIN, 4 SOIL LAYERS, DAILY PRINTOUT
(SWRBMAIL)

	R (MM)	SURQ (MM)	SUB SUR Q (MM)	WATER YIELD (MM)	PERCO LATE (MM)	TRANS LOSSES (MM)	ET (MM)	Y (T/HA)	SW (SW)
1	21.9	.0	.0	.0	.2	.0	13.6	.0	20.2
2	5.3	.0	.0	.0	.0	.0	7.2	.0	18.3
3	22.1	.0	.1	.1	.0	.0	16.4	.0	23.8
4	9.0	.0	.1	.1	.0	.0	10.4	.0	22.4
5	8.9	.0	.1	.0	.0	.0	12.9	.0	18.4
6	21.0	.0	.0	.0	.4	.0	29.4	.0	9.5
7	8.6	.0	.1	.1	.3	.0	17.8	.0	.0
8	3.7	.0	.0	.0	.3	.0	3.4	.0	.1
9	14.3	.0	.0	.0	.5	.0	7.7	.0	6.2
10	14.2	.0	.0	.0	.6	.0	14.5	.0	5.3
11	19.0	.0	.0	.0	.7	.0	10.1	.0	13.4
12	15.9	.0	.1	.1	.1	.0	14.4	.0	14.7
62	164.2	.0	.6	.5	3.1	.0	157.7	.0	14.7

BASIN TRY... TEST FILE USING LOWER SHEEP WEATHER DATA 4/10/86
1 BASIN, 4 SOIL LAYERS, DAILY PRINTOUT
(SWRBMAIL)
FINAL VALUES

```
SUB-BASIN                         SOIL WATER FOR LAYER NO
  NO
       1     2     3     4    TOT
   1   .0  20.7  27.1   1.6  49.5
      FINAL COMPOSITE ST =      14.7 MM
      MIN INDIVIDUAL WATER ST =       .0 MM

                        FINAL CONTENTS
       -----PONDS-----      ---RESERVOIRS---
        WATER     SED        WATER      SED
SUB-BASIN VOL     CONC        VOL       CONC
  NO      (MM)    (PPM)       (MM)      (PPM)
   1       1.6    400.1        1.6     250.2
      FINAL COMPOSITE POND ST =    1.58 MM
      FINAL COMPOSITE RESERVOIR ST =     1.61 MM

      GENERATOR SEEDS
              9 842  35 668
            405  28 481  85
             43  54  68  96
             17  27 948  60
            885  41 676 539
            773 220  79   0
            627  57 929  37
             54  91  65   4
            320  37 631  49

      SOIL WATER BALANCE =      -.209207E+00 MM

      POND BALANCE
      Q =       .659112E-05 MM      Y =    -.290662E-08 T/HA

      RESERVOIR BALANCE
      Q =      -.672036E-06 MM      Y =       .000000E+00 T/HA

   BASIN TRY... TEST FILE USING LOWER SHEEP WEATHER DATA 4/10/86
   1 BASIN, 4 SOIL LAYERS, DAILY PRINTOUT
    (SWRBMAIL)
   SUB-BASIN STATISTICS

             AVE ANNUAL VALUES
                                SUB                  TOTAL
SUB-BASIN RAIN     SUR Q      SUR Q       Y        BIOMASS
  NO      (MM)     (MM)       (MM)     (T/HA)     (KG/HA)
   1     552.8       .0        2.6        .0      5778.5


   BASIN STATISTICS

             STD DEV OF RAIN STORMS
                  5.584

      CN--MEAN = 58.965      MAX = 73.302      MIN = 56.274

      PRED PK FLOW
             MEAN =        .007 M**3/S      ST DEV =       .000 M**3/S
             MEAN PK/VOL =      1.345 M**3/S/MM      NO PKS =          1
```

```
          MAX =          .007 M**3/S

     PRED MO WATER YLD
          MEAN =       .04 MM
          ST DEV =       .03 MM

BASIN TRY... TEST FILE USING LOWER SHEEP WEATHER DATA 4/10/86
1 BASIN, 4 SOIL LAYERS, DAILY PRINTOUT
 (SWRBMAIL)
     AVE ANNUAL BASIN VALUES

          PRECIP =   164.2 MM
          SNOW FALL =   14.35 MM
          SNOW MELT =   12.03 MM
          PRED SURFACE Q =       .01 MM
          SUB-SUR Q =     .64 MM
          PRED H2O YLD =        .51 MM
          DEEP PERC =     3.10 MM
          ET =    157.7 MM
          TRANS LOSSES =        .00 MM
          TOTAL SUB-BASIN SED YLD =        .004 T/HA
          BASIN SED YLD =       .003 T/HA
          POND BUDGET
               EVAPORATION =    15.849 MM
               SEEPAGE =   11.971 MM
               RAINFALL ON POOL =    9.375 MM
               INFLOW
                    Q =      .023 MM
                    Y =      .001 T/HA
               OUTFLOW
                    Q =      .000 MM
                    Y =      .000 T/HA
          RESERVOIR BUDGET
               EVAPORATION =       .471 MM
               SEEPAGE =      .308 MM
               RAINFALL ON POOL =       .230 MM
               INFLOW
                    Q =    2.159 MM
                    Y =      .017 T/HA
               OUTFLOW
                    Q =      .000 MM
                    Y =      .000 T/HA
          YIELD LOSS FROM PONDS
               Q =    .001 MM
               Y =    .004 T/HA
          YIELD LOSS FROM RESERVOIRS
               Q =    .128 MM
               Y =    .001 T/HA
```

BASIN TRY... TEST FILE USING LOWER SHEEP WEATHER DATA 4/10/86
1 BASIN, 4 SOIL LAYERS, DAILY PRINTOUT
(SWRBMAIL)

NO YRS = 1
BASIN AREA = 538.200 KM**2
AVE A RAINFALL/AVE A FOR GAGE = 1.000
TP-40 RAINFALL AMOUNTS (10 YR FREQ) FOR DUR
0.5 H = 56.00MM
6H=108.00MM
NO YRS RECORD MAX .5H RAIN = 8.0
SED RT COEF
AGGRAATION = .10000E-01
DEGRAATION = .27880E-03
LATITUDE = 35.10DEG
BASIN LAG TIME= 30.00D

GENERATOR CYCLES = 0

GENERATOR SEEDS

9	98	915	92
135	28	203	85
43	54	619	33
645	9	948	65
885	41	696	62
51	78	648	0
227	57	929	37
205	90	215	31
320	73	631	49

BASIN TRY... TEST FILE USING LOWER SHEEP WEATHER DATA 4/10/86
1 BASIN, 4 SOIL LAYERS, DAILY PRINTOUT
(SWRBMAIL)
CLIMATE DATA

RAINFALL DATA USED IN THIS RUN ARE:
MEASURED MULTIPLE RAINGAGES

TEMPERATURE DATA USED IN THIS RUN ARE;
SIMULATED SINGLE TEMP

-MO RAIN PROB--		-MO STATS FOR DAILY RAIN-		
W/D	W/W	MEAN	ST DV	SKW CF
.078	.300	5.560	7.720	1.127
.120	.333	5.490	6.810	.860
.132	.304	8.360	10.080	1.220
.159	.417	9.170	11.380	.730
.177	.427	14.350	21.260	2.342
.224	.378	11.280	15.700	2.953
.122	.346	10.690	13.660	1.492
.178	.361	9.910	15.010	2.809
.197	.330	16.050	27.480	3.861
.124	.393	9.520	10.970	.380
.124	.342	8.790	13.820	2.720
.125	.341	4.490	6.960	2.629

	R5MX	TMX	TMN	RA	CVT	RAIN	DAYP	ALPH
JAN	8.10	8.94	-3.48	219.50	.34	17.38	3.13	.40
FEB	11.40	11.60	-1.78	290.00	.24	24.30	4.43	.49
MAR	28.40	16.90	3.23	370.30	.22	41.28	4.94	.45

APR	25.10	23.40	9.77	453.10	.15	59.03	6.44	.53
MAY	42.40	27.00	14.01	511.10	.12	104.93	7.31	.45
JUN	55.40	31.60	19.30	553.50	.07	89.54	7.94	.57
JUL	39.10	34.30	21.70	544.30	.06	52.11	4.87	.59
AUG	28.40	32.80	20.30	501.30	.06	66.86	6.75	.51
SEP	31.70	28.40	16.90	392.50	.11	109.34	6.81	.31
OCT	22.90	23.60	9.82	332.00	.14	49.98	5.25	.47
NOV	26.70	16.50	3.58	237.20	.19	41.75	4.75	.42
DEC	13.50	10.80	-1.46	197.40	.27	22.15	4.93	.56
YR	25.96	22.15	9.32	383.52	.16	678.66	67.55	.48

BASIN TRY... TEST FILE USING LOWER SHEEP WEATHER DATA 4/10/86
1 BASIN, 4 SOIL LAYERS, DAILY PRINTOUT
(SWRBMAIL)
SUB-BASIN DATA

SUB-BASIN AREA/BASIN AREA
.297

POND CATCHMENT AREA FRACTION
.195

POND SURFACE AREA(HA)
141.10

MAX POND STORAGE(MM)
24.0

INTIAL POND STORAGE(MM)
20.0

INITIAL SED CONC IN PONDS(PPM)
402.

NORMAL SED CONC IN PONDS(PPM)
400.

SAT CONDUCTIVITY FOR POND AND RESERVOIR BOTTOMS(MM/H)
.08

RESERVOIR CATCHMENT AREA FRACTION
.200

RESERVOIR SURFACE AREA AT EMERGENCY SPILLWAY(HA)
258.57

RESERVOIR STORAGE AT EMERGENCY SPILLWAY(MM)
89.0

RESERVOIR SURFACE AREA AT PRINCIPAL SPILLWAY(HA)
74.66

RESERVOIR STORAGE AT PRINCIPAL SPILLWAY(MM)
29.1

INITIAL RESERVOIR STORAGE(MM)
.0

AVE RESERVOIR RELEASE RATES(M**3/S/KM**2)
.13700

```
    INITIAL SED CONC IN RESERVOIRS(PPM)
  0.

    NORMAL SED CONC IN RESERVOIRS(PPM)
250.

    SAT CONDUCTIVITY OF RESERVOIR BOTTOMS (MM/H)
 .08

    2 COND CN
75.0

    SOIL ALBEDO
 .15

    WATER CONTENT OF SNOW COVER (MM)
  0

    MAIN CHANNEL LENGTH (KM)
 21.90      30.20

    CHANNEL SLUPE(M/M)
 .0038      .0028

    HYDRAULIC CONDUCTIVITY OF CHANNEL ALLUVIUM (MM/H)
10.000     10.000

    CHANNEL N VALUE
 .050       .050

    OVERLAND FLOW N VALUE
 .050       .050

    TRAVEL TIME FROM SUB-BASIN OUTLETS TO BASIN OUTLET(H)
 6.50

    TIME OF CONCENTRATION FOR SUB-BASINS(H)
 3.29       4.30

    RET FLO SED CONC (PPM)
750.

    RET FLO TRAVEL TIME(D)
30.000

    SLOPE LENGTH(M)
 55.

    SLOPE STEEPENESS(M/M)
 .0800

    SOIL ERODIBILITY FACTORS (K)
 .31

    EROSION CONTROL PRACTICE FACTORS(P)
 1.00

    SLOPE LENGTH AND STEEPNESS FACTORS(LS)
 1.42
```

BASIN TRY... TEST FILE USING LOWER SHEEP WEATHER DATA 4/10/86
1 BASIN, 4 SOIL LAYERS, DAILY PRINTOUT
(SWRBMAIL)
SOILS DATA

ST NO	LAYER DEPTH (MM)	POROSITY (MM/MM)	15 BAR SW (MM/MM)	.3 BAR SW (MM/MM)	AVAIL W ST (MM)	INITIAL W ST (MM)	SAT COND (MM/H)
1	10.0	.47	.09	.28	1.9	.5	16.0
2	150.0	.47	.09	.28	26.6	6.8	16.0
3	510.0	.42	.14	.33	68.4	17.4	15.0
4	840.0	.40	.22	.41	62.7	16.0	12.0
TOTALS					159.6	40.6	

MEDIAN SED. PART SIZE = 18.36

INITIAL COMPOSITE ST = 12.1 MM

BASIN TRY... TEST FILE USING LOWER SHEEP WEATHER DATA 4/10/86
1 BASIN, 4 SOIL LAYERS, DAILY PRINTOUT
(SWRBMAIL)

CROP DATA

SUB-BASIN
1 PLANTING DATE = 3/15
HARVEST DATE = 9/15
TILLAGE OPERATION =FALL PLOW
POT HEAT UNITS = 4136. C
AVE C FACTOR = .200
MAX LAI = 3.0

BASIN TRY... TEST FILE USING LOWER SHEEP WEATHER DATA 4/10/86
1 BASIN, 4 SOIL LAYERS, DAILY PRINTOUT
(SWRBMAIL)

	R (MM)	SURQ (MM)	SUB SUR Q (MM)	WATER YIELD (MM)	PERCO LATE (MM)	TRANS LOSSES (MM)	ET (MM)	Y (T/HA)	SW (SW)
1	21.9	.0	.0	.0	.2	.0	13.6	.0	20.2
2	5.3	.0	.0	.0	.0	.0	7.2	.0	18.3
3	22.1	.0	.1	.1	.0	.0	16.4	.0	23.8
4	9.0	.0	.1	.1	.0	.0	10.4	.0	22.4
5	8.9	.0	.1	.0	.0	.0	12.9	.0	18.4
6	21.0	.0	.0	.0	.4	.0	29.4	.0	9.5
7	8.6	.0	.1	.1	.3	.0	17.8	.0	.0
8	3.7	.0	.0	.0	.3	.0	3.4	.0	.1
9	14.3	.0	.0	.0	.5	.0	7.7	.0	6.2
10	14.2	.0	.0	.0	.6	.0	14.5	.0	5.3
11	19.0	.0	.0	.0	.7	.0	10.1	.0	13.4
12	15.9	.0	.1	.1	.1	.0	14.4	.0	14.7
1962	164.2	.0	.6	.5	3.1	.0	157.7	.0	14.7

BASIN TRY... TEST FILE USING LOWER SHEEP WEATHER DATA 4/10/86
1 BASIN, 4 SOIL LAYERS, DAILY PRINTOUT
(SWRBMAIL)
FINAL VALUES

```
SUB-BASIN          SOIL WATER FOR LAYER NO
  NO
+      1     2     3     4   TOT
  1   .0  20.7  27.1  1.6  49.5
      FINAL COMPOSITE ST =    14.7 MM
      MIN INDIVIDUAL WATER ST =      .0 MM

                  FINAL CONTENTS
           -----PONDS-----    ---RESERVOIRS---
           WATER    SED       WATER     SED
SUB-BASIN VOL      CONC       VOL      CONC
  NO       (MM)    (PPM)      (MM)     (PPM)
  1         1.6    400.1       1.6     250.2
      FINAL COMPOSITE POND ST =    1.58 MM
      FINAL COMPOSITE RESERVOIR ST =     1.61 MM

      GENERATOR SEEDS
               9 842  35 668
             405  28 481  85
              43  54  68  96
              17  27 948  60
             885  41 676 539
             773 220  79   0
             627  57 929  37
              54  91  65   4
             320  37 631  49

      SOIL WATER BALANCE =      -.209207E+00 MM

      POND BALANCE
      Q =      .659112E-05 MM      Y =      -.290662E-08 T/HA

      RESERVOIR BALANCE
      Q =     -.672036E-06 MM      Y =       .000000E+00 T/HA

  BASIN TRY... TEST FILE USING LOWER SHEEP WEATHER DATA 4/10/86
  1 BASIN, 4 SOIL LAYERS, DAILY PRINTOUT
   (SWRBMAIL)
  SUB-BASIN STATISTICS

               AVE ANNUAL VALUES
                              SUB                     TOTAL
SUB-BASIN RAIN      SUR Q     SUR Q       Y          BIOMASS
  NO       (MM)     (MM)      (MM)      (T/HA)      (KG/HA)
  1       552.8       .0       2.6         .0        5778.5


  BASIN STATISTICS

            STD DEV OF RAIN STORMS
                  5.584

      CN--MEAN = 58.965      MAX = 73.302      MIN = 56.274

      PRED PK FLOW
           MEAN =       .007 M**3/S      ST DEV =      .000 M**3/S
           MEAN PK/VOL =      1.345 M**3/S/MM      NO PKS =        1
```

```
        MAX =        .007 M**3/S

    PRED MO WATER YLD
        MEAN =      .04 MM
        ST DEV =     .03 MM

BASIN TRY... TEST FILE USING LOWER SHEEP WEATHER DATA 4/10/86
1 BASIN, 4 SOIL LAYERS, DAILY PRINTOUT
 (SWRBMAIL)
    AVE ANNUAL BASIN VALUES

        PRECIP =     164.2 MM
        SNOW FALL =   14.35 MM
        SNOW MELT =    12.03 MM
        PRED SURFACE Q =      .01 MM
        SUB-SUR Q =    .64 MM
        PRED H2O YLD =       .51 MM
        DEEP PERC =    3.10 MM
        ET =    157.7 MM
        TRANS LOSSES =      .00 MM
        TOTAL SUB-BASIN SED YLD =     .004 T/HA
        BASIN SED YLD =      .003 T/HA
        POND BUDGET
             EVAPORATION =    15.849 MM
             SEEPAGE =   11.971 MM
             RAINFALL ON POOL =    9.375 MM
             INFLOW
                  Q =     .023 MM
                  Y =     .001 T/HA
             OUTFLOW
                  Q =     .000 MM
                  Y =     .000 T/HA
        RESERVOIR BUDGET
             EVAPORATION =      .471 MM
             SEEPAGE =      .308 MM
             RAINFALL ON POOL =      .230 MM
             INFLOW
                  Q =    2.159 MM
                  Y =     .017 T/HA
             OUTFLOW
                  Q =     .000 MM
                  Y =     .000 T/HA
        YIELD LOSS FROM PONDS
             Q =     .001 MM
             Y =     .004 T/HA
        YIELD LOSS FROM RESERVOIRS
             Q =     .128 MM
             Y =     .001 T/HA
```

1

```
*********************************************************************
*                       E N T E R A C T
*
*          INTERACTIVE DATA INPUT SYSTEM   PC VERSION 02/12/86
*                        F O R   S W R R B
*
*********************************************************************
 SECTION 1  --TITLE CARDS
 ENTER TITLE 1:
●DEMONSTRATION OF SWRRB DATA ENTRY PROGRAM
 ENTER TITLE 2:
●SAMPLE DATA
 ENTER TITLE 3:
●REYNOLDS CREEK, IDAHO  AGRICULTURAL RESEARCH SERVICE
 SECTION 2  --PROGRAM CONTROL CARDS
 NUMBER OF YEARS OF RUNOFF SIMULATION

●1
 BEGINNING YEAR OF RUNOFF SIMULATION

●1972
 NUMBER OF SUBAREAS IN BASIN

●2
 NUMBER OF SOIL LAYERS

●4
 PRINT CODE        0 = MONTHLY
                   1 = DAILY    2 = ANNUAL
●0
 RAINFALL INPUT CODE    1=MEASURED SINGLE    2=SIMULATED SINGLE
                        3=MEASURED MULTIPLE  4=SIMULATED MULTIPLE


●1
 TEMPERATURE INPUT CODE
  1=MEAS MAX/MIN   2=SIM SINGLE   3=SIM MULTI
●1
 NUMBER OF TIMES RANDOM NUMBER GEN CYCLES BEFORE SIMULATION BEGINS

●0
 CODE HYDROGRAPH UNIT   0 = SKIP HYD. CALCULATION
                        1 = CALCULATE & PRINT HYDROGRAPH
●0
 WAS LAST VALUE CORRECT AND OK TO WRITE? (Y/N)
   11972   2   4   0   1   1   0   0
●Y
 SECTION 3  --GENERAL DATA
 BASIN AREA                                      KM**2

●538
 RAINFALL CORRECTION
 (RATIO OF AVERAGE ANNUAL RAINFALL TO AVERAGE ANNUAL FOR GAGE)

● 1.0
```

E1
-1

```
TP-40 TEN YEAR FREQUENCY 0.5 HOUR RAINFALL                      (MM)
•19
TP-40 TEN YEAR FREQUENCY 6.0 HOUR RAINFALL                      (MM)
•44.5
NUMBER OF YEARS OF MAXIMUM MONTHLY .5 HOUR RAINFALL RECORD
•31
SEDIMENT ROUTING COEFFICIENT (AGGRADATION)
•.01
SEDIMENT ROUTING COEFFICIENT (DEGGRADATION)
•.0002788
LATITUDE OF WATERSHED                                           DEG
•43.57
BASIN LAG TIME                                                  (D)
•2
FRACTION OF FIELD CAPACITY
 (0.0 ALLOWS SWRRB TO ESTIMATE)
•0.0
WAS LAST VALUE CORRECT AND OK TO WRITE? (Y/N)
538.00   1.00  19.00  44.50  31.00   .01   .00  43.57   2.00    .00
•Y
WILL YOU BE ACCESSING THE WEATHER FILE? (Y/N)
•Y
     WEATHER RETRIEVER     ENTER 4 NUMBER CODE TO SEARCH FOR :
•0032
   32      ID   POCATELLO
  AVERAGE MONTHLY MAXIMUM/MINIMUM TEMPERATURES
  -.2    2.5    7.8   15.4   20.7   25.4   32.0   30.8   25.0  17.7   7.4   2.
-10.6   -7.9   -3.6     .7    4.9    8.7   12.8   11.5    6.4   1.3  -4.2  -7.
  COEFFICIENT OF VARIANCE FOR MONTHLY TEMPERATURE
  .42    .30    .24    .14    .12    .10    .07    .16    .10   .14   .21   .3
  AVERAGE MONTHLY SOLAR RADIATION
 162.   239.   354.   461.   551.   591.   601.   539.   431.  285.  175.  130
  MONTHLY MAXIMUM .5H RAIN FOR PERIOD OF RECORD (MM)
 2.03   3.05   2.79   3.05   3.56   7.87  12.70   3.81   4.57 13.72  3.05  1.7
  MONTHLY PROBABILITY OF WET DAY AFTER DRY DAY/WET DAY AFTER WET DAY
 .289   .253   .230   .213   .194   .169   .095   .107   .099  .110  .194  .25
 .511   .524   .479   .380   .508   .509   .286   .360   .353  .370  .450  .54
  MONTHLY MEAN OF DAILY RAINFALL EVENTS
 2.29   2.03   2.03   3.81   3.30   3.81   2.54   3.56   3.05  3.81  2.79  2.3
  MONTHLY STANDARD DEVIATION OF DAILY RAINFALL EVENTS
 3.05   2.54   2.03   3.81   4.57   4.83   3.81   4.83   4.06  4.83  3.30  2.7
  MONTHLY SKEW OF DAILY RAINFALL EVENTS
 3.04   2.38   2.14   1.93   2.93   2.11   3.75   2.24   3.00  3.21  2.43  2.6

 *****THE WEATHER PORTION OF YOUR FILE HAS BEEN WRITTEN ****

FRACTION OF BASIN IN EACH SUBAREA                  (ONE VALUE/SUB-BASIN)
                                                     (FREE FORMAT)
• .6
• .4
WAS LAST VALUE CORRECT AND OK TO WRITE? (Y/N)
RECORD TO WRITE:
   .600    .400
```

GET FROM STATION LISTS IN APPENDIX

USE CONSTANTS SHOWN HERE

RESPONSE OF THE SUBSURFACE FLOW. LAG TIME IN DAYS.

IF NO BE PREPARED TO INPUT WEATHER INFO.

← GET FROM CITYLIST. NEXT 2 PAGES

0001	AL	BIRMINGHAM
0002	AL	MOBILE
0003	AL	MONTGOMERY
0004	AR	FORT SMITH
0005	AR	LITTLE ROCK
0006	AZ	FLAGSTAFF
0007	AZ	PHOENIX
0008	AZ	YUMA
0009	CA	BAKERSFIELD
0010	CA	BLUE CANYON
0011	CA	EUREKA
0012	CA	FRESNO
0013	CA	MT. SHASTA
0014	CA	SAN DIEGO
0015	CA	SAN FRANCISCO
0016	CO	COLORADO SPRINGS
0017	CO	DENVER
0018	CO	GRAND JUNCTION
0019	CO	PUEBLO
0020	CT	HARTFORD (WINDSOR LOCKS)
0021	DE	WILMINGTON
0022	DC	WASHINGTON
0023	FL	JACKSONVILLE
0024	FL	MIAMI
0025	FL	TALLAHASSEE
0026	FL	TAMPA
0027	GA	GEORGIA
0028	GA	AUGUSTA
0029	GA	MACON
0030	GA	SAVANAH
0031	ID	BOISE
0032	ID	POCATELLO
0033	IL	CHICAGO
0034	IN	EVANSVILLE
0035	IN	FORT WAYNE
0036	IN	INDIANAPOLIS
0037	IA	DES MOINES
0038	IA	DUBUQUE
0039	KS	DODGE CITY
0040	KS	TOPEKA
0041	KS	WICHITA
0042	KY	LEXINGTON
0043	KY	LOUISVILLE
0044	LA	BATON ROUGE
0045	LA	NEW ORLEANS
0046	LA	SHREVEPORT
0047	ME	CARIBOU
0048	ME	PORTLAND
0049	MD	BALTIMORE
0050	MA	BOSTON
0051	MA	NANTUCKET
0052	MI	DETROIT
0053	MI	GRAND RAPIDS
0054	MN	DULUTH
0055	MN	MINNEAPOLIS
0056	MS	JACKSON
0057	MO	COLUMBIA
0058	MO	KANSAS CITY
0059	MO	ST. LOUIS
0060	MT	BILLINGS
0061	MT	GREAT FALLS
0062	MT	HAVRE
0063	MT	HELENA
0064	MT	KALISPELL
0065	MT	MILES CITY
0066	NE	GRAND ISLAN
0067	NE	NORTH PLATT
0068	NE	SCOTTSBLUFF
0069	NV	ELKO
0070	NV	LAS VEGAS
0071	NV	RENO
0072	NV	WINNEMUCCA
0073	NH	CONCORD
0074	NH	MT. WASHING
0075	NJ	NEWARK
0076	NM	ALBUQUERGUE
0077	NM	ROSWELL
0078	NY	ALBANY
0079	NY	BUFFALO
0080	NY	NEW YORK
0081	NY	SYRACRUSE
0082	NC	ASHEVILLE
0083	NC	GREENSBORO
0084	NC	RALEIGH
0085	ND	BISMARCK
0086	ND	WILLISTON
0087	OH	CLEVELAND
0088	OH	COLUMBUS

CITYLIST.DAT;1

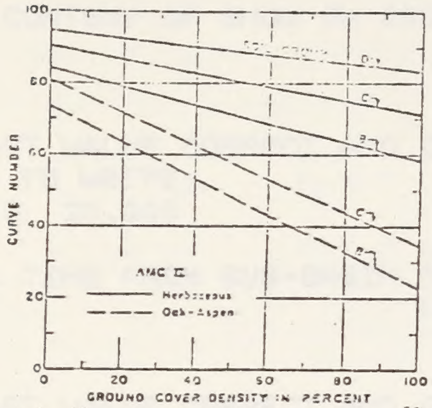
0089	OH	TOLEDO
0090	OK	OKLAHOMA CITY
0091	OK	TULSA
0092	OR	BURNS
0093	OR	MEACHUM
0094	OR	MEDFORD
0095	OR	PENDLETON
0096	OR	PORTLAND
0097	OR	SALEM
0098	OR	SEXTON SUMMIT
0099	PA	PHILADELPHIA
0100	PA	PITTSBURGH
0101	RI	PROVIDENCE
0102	SC	CHARLESTON
0103	SC	COLUMBIA
0104	SD	HURON
0105	SD	RAPID CITY
0106	TN	CHATTONOOGA
0107	TN	KNOXVILLE
0108	TN	MEMPHIS
0109	TN	NASHVILLE
0110	TX	AMARILLO
0111	TX	AUSTIN
0112	TX	BROWNSVILLE
0113	TX	CORPUS CHRISTI
0114	TX	DALLAS
0115	TX	EL PASO
0116	TX	GALVESTON
0117	TX	HOUSTON
0118	TX	SAN ANTONIO

CITYLIST.DAT;1

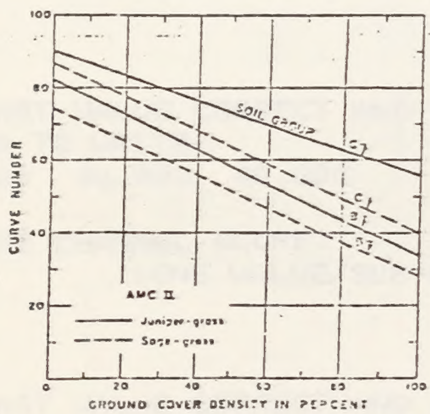
0119	TX	WACO
0120	UT	MILFORD
0121	UT	SALT LAKE CITY
0122	VA	NORFOLK
0123	VA	RICHMOND
0124	WA	OLYMPIA
0125	WA	SPOKANE
0126	WA	STAMPEDE PASS
0127	WA	WALLA WALLA
0128	WA	YAKIMA
0129	WV	CHARLESTON
0130	WI	GREEN BAY
0131	WI	LA CROSSE
0132	WI	MADISON
0133	WI	MILWAUKEE
0134	WY	CHEYENNE

• Y

SCS RUNOFF CURVE NUMBER - CONDITION II (ONE VALUE/SUB-BASIN) (FREE FORMAT)



Graph for estimating runoff curve numbers of forest-range complexes in western United States: herbaceous and oak-aspen complexes.



Graph for estimating runoff curve numbers of forest-range complexes in western United States: juniper-grass and sage-grass complexes.

Runoff curve numbers for hydrologic soil-cover complexes

(Antecedent moisture condition II, and $I_a = 0.2\ S$)

Land use	Cover: Treatment or practice	Cover: Hydrologic condition	Hydrologic soil group A	B	C	D
Fallow	Straight row	----	77	86	91	94
Row crops	"	Poor	72	81	88	91
	"	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	"	Good	65	75	82	86
	"and terraced	Poor	66	74	80	82
	" " "	Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	"and terraced	Poor	61	72	79	82
		Good	59	70	78	81
Close-seeded legumes 1/ or rotation meadow	Straight row	Poor	66	77	85	89
	" "	Good	58	72	81	85
	Contoured	Poor	64	75	83	85
	"	Good	55	69	78	83
	"and terraced	Poor	63	73	80	83
	"and terraced	Good	51	67	76	80
Pasture or range		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
	"	Fair	25	59	75	83
	"	Good	6	35	70	79
Meadow		Good	30	58	71	78
Woods		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads		----	59	74	82	86
Roads (dirt) 2/		----	72	82	87	89
(hard surface) 2/		---	74	84	90	92

1/ Close-drilled or broadcast.
2/ Including right-of-way.

Taken from the SCS National Engineering Handbook (7).

Runoff curve numbers for hydrologic soil-cover complexes of a typical watershed in Contra Costa County, California (antecedent moisture condition II, and $I_a = 0.2\ S$).

Cover	Condition	Hydrologic soil group A	B	C	D
Scrub (native brush)	----	25-30	41-46	57-63	66
Grass-oak (native oaks with understory of forbs and annual grasses)	Good	29-33	43-48	59-65	67
Irrigated pasture	Good	32-37	46-51	62-68	70
Orchard (winter period with understory of cover crop)	Good	37-41	50-55	64-69	71
Range (annual grass)	Fair	46-49	57-60	68-72	74
Small grain (contoured)	Good	61-64	69-71	76-80	81
Truck crops (straight-row)	Good	67-69	74-76	80-83	84
Urban areas:					
Low density (15 to 18 percent impervious surfaces)		69-71	75-78	82-84	86
Medium density (21 to 27 percent impervious surfaces)		71-73	77-80	84-86	88
High density (50 to 75 percent impervious surfaces)		73-75	79-82	86-88	90

```
SOIL ALBEDO                                        (ONE VALUE/SUB-BASIN)
                                                     (FREE FORMAT)
• .15
• .15
 WAS LAST VALUE CORRECT AND OK TO WRITE? (Y/N)
 RECORD TO WRITE:
    .150    .150
• Y
 WATER CONTENT OF SNOW ON GROUND AT START OF SIMULATION (MM)
                               (ONE VALUE/SUB-BASIN)(FREE FORMAT)
• 20
• 25
 WAS LAST VALUE CORRECT AND OK TO WRITE? (Y/N)
 RECORD TO WRITE:
  20.000  25.000
• Y
 TRAVEL TIME FROM SUB-BASIN OUTLETS TO BASIN OUTLET        HOURS
                              (ONE VALUE/SUB-BASIN)(FREE FORMAT)
• 2
• 0
 WAS LAST VALUE CORRECT AND OK TO WRITE? (Y/N)
 RECORD TO WRITE:
   2.000    .000
• Y
 CHANNEL LENGTH FROM MOST DISTANT POINT TO THE SUB-BASIN OUTLET (KM)
          (ONE VALUE/SUB-BASIN+ONE FOR ENTIRE BASIN)(FREE FORMAT)
• 30
• 40
• 40
 WAS LAST VALUE CORRECT AND OK TO WRITE? (Y/N)
 RECORD TO WRITE:
  30.000  40.000  40.000
• Y
 AVERAGE CHANNEL SLOPE                                       (M/M)
          (ONE VALUE/SUB-BASIN+ONE FOR ENTIRE BASIN)(FREE FORMAT)
• .005
• .006
• .006
 WAS LAST VALUE CORRECT AND OK TO WRITE? (Y/N)
 RECORD TO WRITE:
    .005    .006    .006
• Y
```

EFFECTIVE HYDRAULIC CONDUCTIVITY
IN CHANNELS ALLUVIUM (MM)

• 10.0   10.0   10.0

Effective hydraulic conductivity for transmission losses in channel alluvium.

Bed material group	Bed material characteristics	Effective hydraulic conductivity (millimeters/hour)
1 Very high loss rate	Very clean gravel and large sand. d_{50} >2 mm	>127
2 High loss rate	Clean sand and gravel under field conditions. d_{50} > 2 mm	51-127
3 Moderately high loss rate	Sand and gravel mixture with less than a few percent silt-clay.	25-76
4 Moderate loss rate	Mixture of sand and gravel with significant amounts of silt-clay.	6.4-25
5 Very low loss rate	Consolidated bed material with high silt-clay content.	0.025-2.5

Taken from: Lane, L. J. 1982. Distributed model for small semiarid watersheds. J. Hydraulics Division, ASCE, Vol. 108, No. HY10, October. pp. 1114-1131.

CHANNEL N VALUE
(ONE VALUE/SUB-BASIN+ONE FOR ENTIRE BASIN)(FREE FORMAT)

• .05
• .07
• .07

Values of Manning's roughness factor "n".

	Value chosen	Range
I. Channel Flow[1/]		
A. Excavated or dredged		
1. Earth, straight and uniform	0.025	0.016-0.033
2. Earth, winding and sluggish	0.035	0.023-0.05
3. Not maintained, weeds and brush	0.075	0.04-0.14
B. Natural streams		
1. Few trees, stones, or brush	0.05	0.025-0.065
2. Heavy timber and brush	0.10	0.05-0.15
II. Overland Flow[2/]		
Fallow, no residue	0.01	0.008-0.012
Conventional tillage, no residue	0.09	0.06-0.12
Conventional tillage, residue	0.19	0.16-0.22
Chisel plow, no residue	0.09	0.06-0.12
Chisel plow, residue	0.13	0.10-0.16
Fall disking, residue	0.40	0.30-0.50
No till, no residue	0.07	0.04-0.10
No till (0.5-1 t ha^{-1})	0.12	0.07-0.17
No till (2-9 t ha^{-1})	0.30	0.17-0.47
Rangeland (20% cover)	0.60	
Short grass prairie	0.15	0.10-0.20
Dense grass	0.24	0.17-0.30
Bermudagrass	0.41	0.30-0.48

1/ Taken from Chow (2).
2/ Taken from Engman (3).

```
 WAS LAST VALUE CORRECT AND OK TO WRITE? (Y/N)
 RECORD TO WRITE:
    .050    .070    .070
● Y
 OVERLAND FLOW N VALUE
            (ONE VALUE/SUB-BASIN+ONE FOR ENTIRE BASIN)(FREE FORMAT)
● .1
● .2
● .2
 WAS LAST VALUE CORRECT AND OK TO WRITE? (Y/N)
 RECORD TO WRITE:
    .100    .200    .200
● Y
 RETURN FLOW TRAVEL TIME                                  (DAYS)
                              (ONE VALUE/SUB-BASIN)(FREE FORMAT)
● 30
● 35
 WAS LAST VALUE CORRECT AND OK TO WRITE? (Y/N)
 RECORD TO WRITE:
  30.000  35.000
● Y
 SEDIMENT CONCENTRATION IN RETURN FLOW                     (PPM)
                             (ONE VALUES/SUB-BASIN)(FREE FORMAT)
● 200
● 250
 WAS LAST VALUE CORRECT AND OK TO WRITE? (Y/N)
 RECORD TO WRITE:
 200.000 250.000
● Y
 USLE SOILS FACTOR K
                             (ONE VALUES/SUB-BASIN)(FREE FORMAT)
● .35
● .3
 WAS LAST VALUE CORRECT AND OK TO WRITE? (Y/N)
 RECORD TO WRITE:
    .350    .300
● Y
```

SOIL SURVEY

4.--PHYSICAL AND CHEMICAL PROPERTIES OF SOILS--Continued

Soil name and map symbol	Depth	Clay	Moist bulk density	Permea-bility	Available water capacity	Soil reaction	Salinity	Shrink-swell potential	Erosion factors K	Erosion factors T	Wind erodi-bility group	Organic matter
	In	Pct	G/cm3	In/hr	In/in	pH	Mmhos/cm					Pct
32*, 33*:												
Chilcott--------	0-9	12-18	1.40-1.50	0.6-2.0	0.19-0.21	6.6-7.8	<2	Low--------	0.49	2	5	1-2
	9-15	35-60	1.20-1.40	0.06-0.2	0.14-0.21	7.4-7.8	<2	High-------	0.32			
	15-26	12-35	1.40-1.60	0.2-0.6	0.16-0.21	7.4-8.4	<2	Moderate	0.43			
	26-35	---	---	---	---	---	---	-----------	---			
	35-65	2-10	1.60-1.70	2.0-6.0	0.03-0.13	7.9-8.4	<2	Low--------	0.10			
Brent-----------	0-5	15-20	1.35-1.45	0.6-2.0	0.16-0.18	6.6-7.3	<2	Low--------	0.49	5	5	1-2
	5-18	15-20	1.40-1.50	0.6-2.0	0.16-0.21	7.4-7.8	<2	Low--------	0.49			
	18-40	35-55	1.20-1.40	<0.06	0.14-0.17	7.4-8.4	<2	High-------	0.24			
	40-46	25-40	1.40-1.50	0.2-0.6	0.19-0.21	7.9-8.4	<2	Moderate	0.24			
	46-64	5-10	1.60-1.70	6.0-20	0.05-0.08	7.9-8.4	<2	Low--------	0.15			
34*, 35*, 36*:												
Chilcott--------	0-9	12-18	1.40-1.50	0.6-2.0	0.19-0.21	6.6-7.8	<2	Low--------	0.49	2	5	1-2
	9-15	35-60	1.20-1.40	0.06-0.2	0.14-0.21	7.4-7.8	<2	High-------	0.32			
	15-26	12-35	1.40-1.60	0.2-0.6	0.16-0.21	7.4-8.4	<2	Moderate	0.43			
	26-35	---	---	---	---	---	---	-----------	---			
	35-65	2-10	1.60-1.70	2.0-6.0	0.03-0.13	7.9-8.4	<2	Low--------	0.10			
Sebree----------	0-7	30-35	1.40-1.50	0.2-0.6	0.19-0.21	6.1-7.8	8-16	Moderate	0.37	2	7	.5-1
	7-30	27-35	1.40-1.50	0.06-0.2	0.19-0.21	7.4-9.0	>8	Moderate	0.32			
	30-34	20-27	1.40-1.50	0.06-0.2	0.19-0.21	7.4-9.0	>8	Low--------	0.32			
	34-42	---	---	---	---	---	---	-----------	---			
	42-60	2-8	1.60-1.70	>20	0.03-0.08	7.4-9.0	<2	Low--------	0.15			
37*, 38*, 39*:												
Chilcott--------	0-9	12-18	1.40-1.50	0.6-20	0.19-0.21	6.6-7.8	<2	Low--------	0.49	2	5	1-2
	9-15	35-60	1.20-1.40	0.06-0.2	0.14-0.21	7.4-7.8	<2	High-------	0.32			
	15-26	12-35	1.40-1.60	0.2-2.0	0.16-0.21	7.4-8.4	<2	Moderate	0.43			
	26-47	---	---	---	---	---	---	-----------	---			
	47	---	---	---	---	---	---	-----------	---			
Sebree----------	0-7	30-35	1.40-1.50	0.2-0.6	0.19-0.21	6.1-7.8	8-16	Moderate	0.37	2	7	.5-1
	7-30	27-35	1.40-1.50	0.06-0.2	0.19-0.21	7.4-9.0	>8	Moderate	0.32			
	30-34	20-25	1.50-1.60	0.6-2.0	0.19-0.21	7.4-9.0	>8	Low--------	0.43			
	34-42	---	---	---	---	---	---	-----------	---			
	42	---	---	---	---	---	---	-----------	---			

USLE EROSION CONTROL PRACTICE FACTOR P.
(ONE VALUES/SUB-BASIN)(FREE FORMAT)

- 1
- 1

SUPPORT PRACTICE FACTOR (P)

In general, whenever sloping soil is to be cultivated and exposed to erosive rains, the protection offered by sod or close-growing crops in the system needs to be supported by practices that will slow the runoff water and thus reduce the amount of soil it can carry. The most important of these supporting cropland practices are contour tillage, stripcropping on the contour, and terrace systems. Stabilized waterways for the disposal of excess rainfall are a necessary part of each of these practices.

By definition, factor P in the USLE is the ratio of soil loss with a specific support practice to the corresponding loss with up-and-down-slope culture. Improved tillage practices, sod-based rotations, fertility treatments, and greater quantities of crop residues left on the field contribute materially to erosion control and frequently provide the major control in a farmer's field. However, these are considered conservation cropping and management practices, and the benefits derived from them are included in C.

P values and slope-length limits for contouring

Land slope percent	P value	Maximum length[1]
		Feet
1 to 2	0.60	400
3 to 5	.50	300
6 to 8	.50	200
9 to 12	.60	120
13 to 16	.70	80
17 to 20	.80	60
21 to 25	.90	50

[1] Limit may be increased by 25 percent if residue cover after crop seedlings will regularly exceed 50 percent.

P values for contour-farmed terraced fields[1]

Land slope (percent)	Farm planning		Computing sediment yield[3]	
	Contour factor[2]	Stripcrop factor	Graded channels sod outlets	Steep backslope underground outlets
1 to 2	0.60	0.30	0.12	0.05
3 to 8	.50	.25	.10	.05
9 to 12	.60	.30	.12	.05
13 to 16	.70	.35	.14	.05
17 to 20	.80	.40	.16	.06
21 to 25	.90	.45	.18	.06

[1] Slope length is the horizontal terrace interval. The listed values are for contour farming. No additional contouring factor is used in the computation.

[2] Use these values for control of interterrace erosion within specified soil loss tolerances.

[3] These values include entrapment efficiency and are used for control of offsite sediment within limits and for estimating the field's contribution to watershed sediment yield.

P values, maximum strip widths, and slope-length limits for contour stripcropping

Land slope percent	P values[1] A	B	C	Strip width[2]	Maximum length
				Feet	*Feet*
1 to 2	0.30	0.45	0.60	130	800
3 to 5	.25	.38	.50	100	600
6 to 8	.25	.38	.50	100	400
9 to 12	.30	.45	.60	80	240
13 to 16	.35	.52	.70	80	160
17 to 20	.40	.60	.80	60	120
21 to 25	.45	.68	.90	50	100

[1] P values:
A For 4-year rotation of row crop, small grain with meadow seeding, and 2 years of meadow. A second row crop can replace the small grain if meadow is established in it.
B For 4-year rotation of 2 years row crop, winter grain with meadow seeding, and 1-year meadow.
C For alternate strips of row crop and small grain.

[2] Adjust strip-width limit, generally downward, to accommodate widths of farm equipment.

USE 1 FOR RANGELANDS THAT ARE NOT PLOWED, Terraced etc.

Taken from Wischmeier and Smith (19).

AVERAGE SLOPE LENGTH FOR EACH SUB-BASIN(M)
(ONE VALUES/SUB-BASIN)(FREE FORMAT)

50.000 80.000 80.000

- Y

AVERAGE SLOPE STEEPNESS FOR EACH SUB-BASIN (M/M)
(ONE VALUES/SUB-BASIN+ONE FOR ENTIRE BASIN)(FREE FORMAT)

- .2
- .15
- .15

WAS LAST VALUE CORRECT AND OK TO WRITE? (Y/N)
RECORD TO WRITE:
.200 .150 .150

- Y

IS POND DATA CONSIDERED? (Y/N)

- N

IS RESERVOIR DATA CONSIDERED? (Y/N)

- N

```
SECTION  9 --SOIL DATA
DEPTH TO BOTTOM OF LAYER          (MM) (ONE VALUE/LAYER,FREE FORMAT)

• 10
• 150
• 510
• 840
WAS LAST VALUE CORRECT AND OK TO WRITE? (Y/N)
RECORD TO WRITE:
 10.000 150.000 510.000 840.000
• Y
BULK DENSITY                  (T/M**3)  (ONE VALUE/LAYER,FREE FORMAT)

• 1.5 1.5 1.5 1.5
WAS LAST VALUE CORRECT AND OK TO WRITE? (Y/N)
RECORD TO WRITE:
  1.500   1.500   1.500   1.500
• Y
AVAILABLE WATER CONTENT        (MM/MM) (ONE VALUE/LAYER,FREE FORMAT)

• .2 .2 .24 .29
WAS LAST VALUE CORRECT AND OK TO WRITE? (Y/N)
RECORD TO WRITE:
   .200    .200    .240    .290
• Y
SATURATED CONDUCTIVITY          (MM/H) (ONE VALUE/LAYER,FREE FORMAT)

• 3 3 8 8
WAS LAST VALUE CORRECT AND OK TO WRITE? (Y/N)
RECORD TO WRITE:
  3.000   3.000   8.000   8.000
• Y
CLAY CONTENT                   (%)    (ONE VALUE/LAYER,FREE FORMAT)

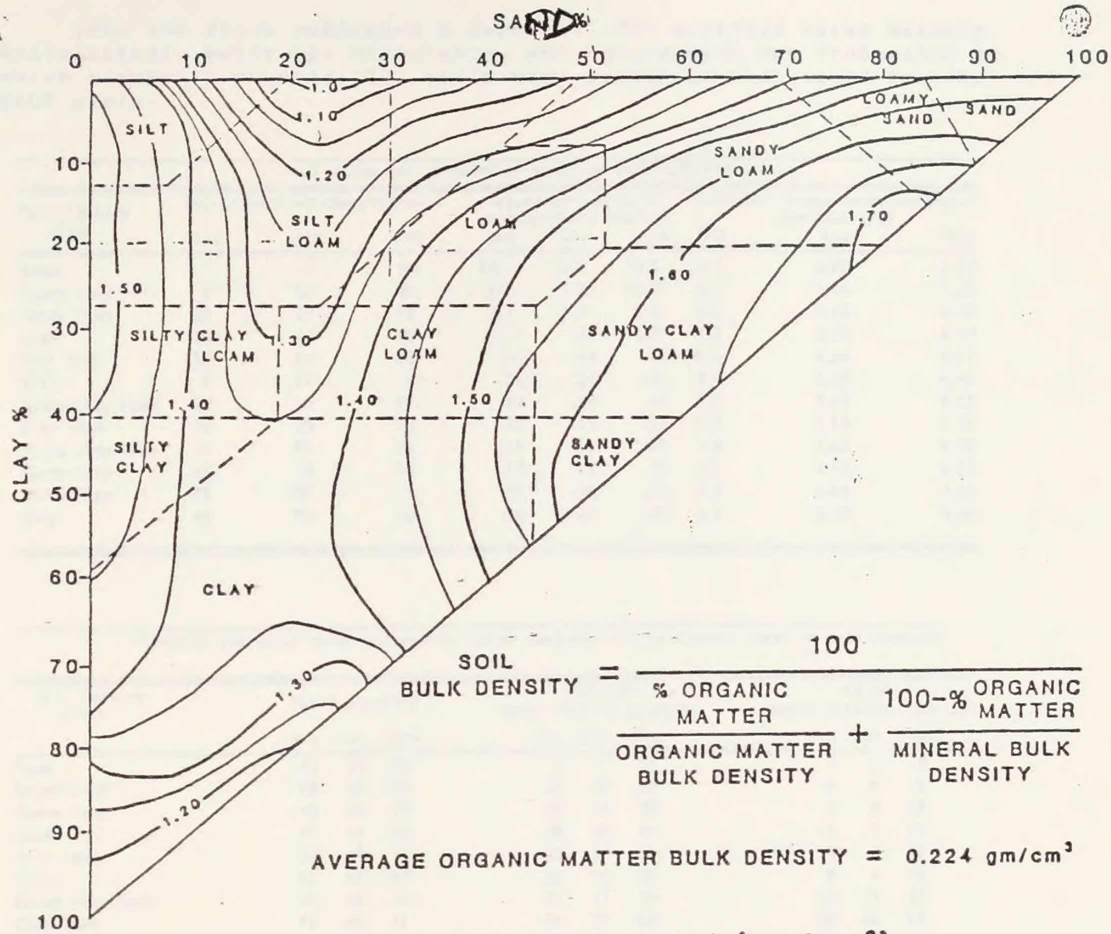
• 30 30 15 20
WAS LAST VALUE CORRECT AND OK TO WRITE? (Y/N)
RECORD TO WRITE:
 30.000  30.000  15.000  20.000
• Y
PASS #200 SIEVE                (%)    (ONE VALUE/LAYER,FREE FORMAT)

• 50  50  30  30
```

SOIL SURVEY

.--ENGINEERING PROPERTIES AND CLASSIFICATIONS--Continued

Soil name and map symbol	Depth	USDA texture	Classification: Unified	Classification: AASHTO	Fragments > 3 inches	Percentage passing sieve number-- 4	10	40	200	Liquid limit	Plasticity index
	In				Pct					Pct	
3*, 39*:											
Chilcott----------	0-9	Stony silt loam	ML, CL-ML	A-4	5-10	95-100	95-100	90-100	80-90	20-30	NP-10
	9-15	Silty clay loam, silty clay, clay.	CL, CH	A-6, A-7	0-5	100	100	90-100	75-95	35-60	15-40
	15-26	Silt loam, clay loam, loam.	CL-ML, CL	A-4, A-6	0-5	100	100	85-100	70-90	25-35	5-15
	26-47	Indurated-------	---	---	---	---	---	---	---	---	---
	47	Unweathered bedrock.	---	---	---	---	---	---	---	---	---
Sebree------------	0-7	Stony silty clay loam.	CL	A-6	5-10	100	100	95-100	85-95	30-40	10-15
	7-30	Silty clay loam, clay loam.	CL	A-6	0-5	100	100	90-100	70-95	30-40	10-15
	30-34	Silt loam, loam	CL-ML	A-4	0-5	100	100	90-100	75-90	25-30	5-10
	34-42	Indurated-------	---	---	---	---	---	---	---	---	---
	42	Unweathered bedrock.	---	---	---	---	---	---	---	---	---



$$\text{SOIL BULK DENSITY} = \frac{100}{\dfrac{\%\ \text{ORGANIC MATTER}}{\text{ORGANIC MATTER BULK DENSITY}} + \dfrac{100-\%\ \text{ORGANIC MATTER}}{\text{MINERAL BULK DENSITY}}}$$

AVERAGE ORGANIC MATTER BULK DENSITY = 0.224 gm/cm³

MINERAL BULK DENSITY (gm/cm³)

Mean physical properties of soils

Texture	Bulk density gm/cm	Volume (in/in) Total porosity	Field capacity 1/3 bar	Wilting point 15 bar	AWC
Coarse sand	1.6	0.40	0.11	0.03	0.08
Sand	1.6	0.40	0.16	0.03	0.13
Find sand	1.5	0.43	0.18	0.03	0.15
V. fine sand	1.5	0.43	0.27	0.03	0.25
L. coarse sand	1.6	0.40	0.16	0.05	0.11
Loamy sand	1.6	0.40	0.19	0.05	0.14
Loamy f. sand	1.6	0.40	0.22	0.05	0.18
L.v.f. sand	1.6	0.40	0.37	0.05	0.32
Coarse s. loam	1.5	0.40	0.19	0.08	0.11
Sandy loam	1.6	0.40	0.22	0.08	0.14
F. sandy loam	1.7	0.36	0.27	0.08	0.19
V.f. sandy loam	1.6	0.40	0.37	0.08	0.29
Loam	1.6	0.40	0.26	0.11	0.15
Silt loam	1.5	0.43	0.32	0.12	0.20
Silt	1.4	0.47	0.27	0.03	0.24
Sandy clay loam	1.5	0.40	0.30	0.18	0.12
Clay loam	1.6	0.40	0.35	0.22	0.13
Silty clay loam	1.4	0.47	0.36	0.20	0.16
Sandy clay	1.6	0.40	0.28	0.20	0.13
Silty clay	1.5	0.48	0.40	0.30	0.14
Clay	1.4	0.47	0.39	0.28	0.11

Lane and Stone published a paper in 1983 entitled Water Balance Calculations, Water Use Efficiency, and Aboveground Net Production in which summaries of over 1300 soils were presented that would benefit HELP users.

--Selected soil properties based on soil textural class.

Soil texture class	Representative composition			Saturated hydraulic conductivity (cm/hr)			Bare soil evaporation parameter c(mm/day 1/2)		
	Clay	Silt	Sand	Avg	Low	High	Avg	Low	High
Sand	3	7	90	23.	11.7	43.2	3.3	3.05	3.32
Loamy sand	5	15	80	6.1	3.6	11.7	3.3	3.05	3.32
Sandy loam	10	20	70	2.2	1.7	3.6	3.5	3.10	4.06
Loam	20	40	40	1.3	.91	1.7	4.5	3.20	4.57
Silt loam	15	65	20	.69	.46	.91	4.5	3.20	4.57
Silt	5	87	8	.51	.30	.61	4.0	3.15	4.40
Sandy clay loam	30	10	60	.30	.25	.46	3.8	3.15	4.32
Clay loam	35	35	30	.20	.19	.25	3.8	3.15	4.32
Silty clay loam	35	55	10	.18	.15	.19	3.8	3.15	4.32
Sandy clay	45	5	50	.13	.11	.15	3.4	3.10	3.56
Silty clay	45	50	5	.10	.09	.11	3.5	3.10	3.31
Clay	65	20	15	.08	.06	.09	3.4	3.10	3.56

-Porosity and water holding capacity (water content in % by volume) based on soil textural class.

Soil texture class	Total porosity			-1/3 Bar Water holding capacity			-15 Bar Water holding capacity		
	Avg	Low	High	Avg	Low	High	Avg	Low	High
Sand	41	39	43	9	7	15	3	2	6
Loamy sand	43	39	45	12	10	20	6	4	8
Sandy loam	45	39	52	20	14	29	9	5	12
Loam	47	45	52	26	20	36	12	9	13
Silt loam	50	49	55	31	29	36	13	7	20
Silt	51	49	55	28	26	30	9	6	12
Sandy clay loam	42	38	45	27	17	34	17	11	21
Clay loam	47	40	51	34	29	38	20	16	24
Silty clay loam	47	46	51	36	33	40	21	18	24
Sandy clay	42	40	44	31	27	40	21	18	30
Silty clay	48	46	49	40	35	46	27	23	32
Clay	49	44	52	42	34	49	29	23	38

ANTECEDENT SOIL WATER CONTENT- The degree of wetness of a watershed at the beginning of a storm. In the SCS method 3 levels of AMC are used:

AMC-I. Lowest runoff potential. The watershed soils are dry enough for satisfactory plowing or cultivation to take place.

AMC-II. The average condition.

AMC-III. Highest runoff potential. The watershed is practically saturated from antecedent rains.

BUBBLING PRESSURE- Used as Pb in the Brooks and Corey equation. It is a characteristic constant of the medium and is a measure of the maximum pore-size forming a continuous network of flow channels within the medium. Approximately the minimum capillary pressure on the drainage cycle at which the non-wetting fluid is continuous.

BULK DENSITY- The ratio of soil mass to the bulk soil volume. Can be calculated as moist or dry bulk density. See Illustration 2.

EFFECTIVE POROSITY- The volume of interconnected pore space that water can be freely removed from. Calculated as porosity minus residual water content.

FINE EARTH FRACTION- The fraction of soil material less than 2 mm. diameter.

POROSITY- The volume of pore space expressed as a fraction of bulk volume of the porous medium.

POROSITY INDEX- Pore size distribution index. Can be any positve value, being small for media having a wide range of pore sizes and large for media with a relatively uniform pore size. Used in the Brooks and Corey equations.

RESIDUAL WATER CONTENT- Volume of water remaining in the pore space after water has been freely removed from the interconnected pore space.

SATURATED HYDRAULIC CONDUCTIVITY- The rate of water movement through a porous media at a saturated soil water content.

WATER CONTENT, 1/3 BAR- The water content at 1/3 bar tension, defines the soil's field capacity.

WATER CONTENT, 15 BAR- The water content at the 15 bar moisture tension that represent the wilting point of many plants. Rangeland plants may have wilting points that are better described at higher moisture tensions.

WATER HOLDING CAPACITY- The difference between water held at 1/3 bar (field capactity) and 15 bar (wilting point). Assummed to be the water available to plants.

WETTING FRONT CAPILLARY PRESSURE- The capillary pressure (tension) of the wet

```
MONTH OF PLANTING
• 1
DAY OF PLANTING
• 1
MONTH OF HARVEST
• 6
DAY OF HARVEST
• 15
VEGETATION CODE              1 = ANNUAL                     2 = PERENNIAL
• 2
TILLAGE OPERATION CODE  1 = FALL PLOW          2 = SPRING PLOW
                        3 = CONSERVATION TILLAGE 4 = ZERO TILLAGE
• 4
WAS LAST VALUE CORRECT AND OK TO WRITE? (Y/N)
  1   1    6   15    2    4
• Y
AVERAGE ANNUAL C FACTOR
• .05
MAXIMUM LEAF AREA INDEX
• 3.5
WAS LAST VALUE CORRECT AND OK TO WRITE? (Y/N)
    .05    3.50
• Y
Stop - Program terminated.
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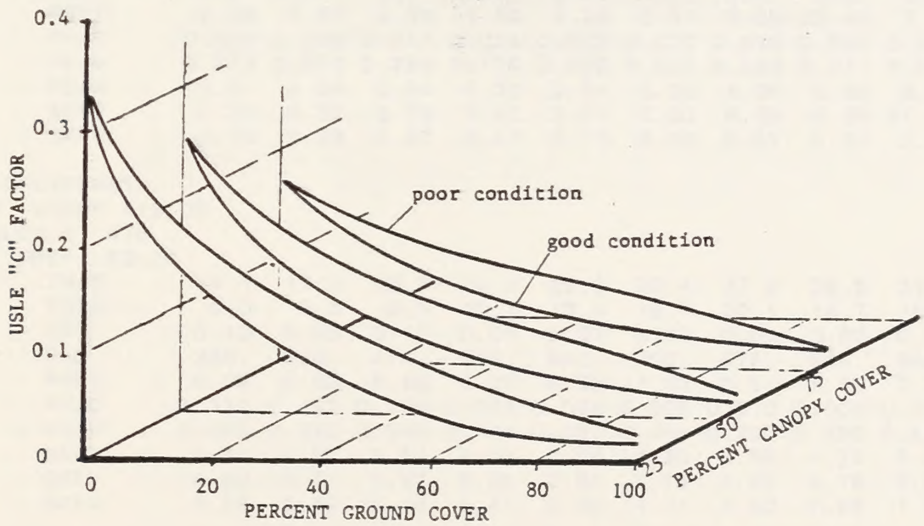

USLE "C" FACTOR FOR TYPICAL RANGELANDS ADAPTED FROM WISCHMEIER AND SMITH (1978) TABLE 10

LAI = C × GRAMS PHYTOMASS (AVE. PEAK STANDING CROP)

C = 0.015 FOR BLUE GRAMMA
0.02 for wheatgrass
0.03 For forbs and shrubs

STA.	ST.	VARIABLE	J	F	M	A	M	J	J	A	S	O	N	D
FLAGSTAFF, ARIZONA														
LATT= 35.08 LONG= 111.40														
YRS= 16. ELEV.= 6993.														
TP5= 50.80 TP6= 88.90														
		TMAX	4.7	5.9	9.7	14.8	19.9	25.2	27.4	26.1	23.7	17.3	10.8	6.6
		TMIN	-9.9	-8.6	-5.8	-2.2	1.1	5.3	9.8	9.3	5.7	-0.7	-6.3	-8.4
		CVT	0.35	0.34	0.25	0.19	0.13	0.11	0.07	0.12	0.10	0.15	0.26	0.33
		RAD	291.	399.	516.	628.	714.	729.	648.	603.	556.	439.	334.	271.
		P5MX	5.08	10.41	5.59	6.60	5.33	5.59	27.94	17.78	10.16	5.33	6.35	3.56
		PW/D	0.114	0.138	0.151	0.127	0.073	0.051	0.254	0.279	0.132	0.082	0.114	0.115
		PW/W	0.558	0.470	0.483	0.464	0.362	0.490	0.545	0.515	0.438	0.470	0.495	0.536
		MEAN	7.37	6.60	6.86	6.10	4.57	6.35	5.84	6.35	7.62	7.11	7.62	9.40
		SDEV	8.38	7.37	8.89	6.35	4.83	11.68	8.38	8.89	11.94	8.89	9.65	12.95
		SKEW	1.99	2.03	3.55	1.57	2.17	3.12	3.61	2.79	2.90	2.23	2.20	2.83
PHOENIX, ARIZONA														
LATT= 33.26 LONG= 112.01														
YRS= 26. ELEV.= 1117.														
TP5= 54.61 TP6= 101.60														
		TMAX	17.8	20.1	23.9	28.8	33.8	38.7	40.3	38.7	36.8	30.4	23.2	18.9
		TMIN	1.8	3.8	6.1	10.2	13.9	18.6	23.9	23.0	19.6	12.6	5.8	2.8
		CVT	0.10	0.10	0.08	0.07	0.06	0.05	0.03	0.07	0.06	0.07	0.08	0.07
		RAD	301.	409.	526.	638.	724.	739.	658.	613.	566.	449.	344.	281.
		P5MX	6.10	5.84	8.64	4.57	14.99	2.54	24.13	31.24	8.38	5.59	6.10	9.14
		PW/D	0.085	0.077	0.070	0.042	0.018	0.022	0.099	0.147	0.057	0.054	0.060	0.078
		PW/W	0.407	0.478	0.364	0.303	0.294	0.313	0.365	0.318	0.429	0.354	0.327	0.400
		MEAN	4.83	3.81	6.10	4.57	3.30	4.32	4.57	5.59	6.35	5.33	5.08	6.10
		SDEV	5.84	4.83	5.59	5.08	4.32	6.86	6.10	8.89	11.94	6.86	5.33	7.37
		SKEW	2.04	2.28	1.10	1.66	2.93	2.27	2.38	4.46	3.06	1.89	1.90	1.86
YUMA, ARIZONA														
LATT= 32.67 LONG= 114.60														
YRS= 15. ELEV.= 194.														
TP5= 31.75 TP6= 62.23														
		TMAX	20.7	23.3	27.1	31.3	35.4	39.7	42.3	41.4	39.7	33.3	25.9	21.6
		TMIN	5.3	6.8	10.1	13.6	17.4	21.7	26.8	25.8	22.7	15.9	9.4	6.2
		CVT	0.10	0.11	0.09	0.08	0.07	0.07	0.05	0.09	0.05	0.09	0.11	0.09
		RAD	269.	374.	500.	600.	648.	712.	656.	616.	556.	422.	326.	262.
		P5MX	8.89	4.57	5.59	2.54	2.29	0.51	3.05	25.40	3.56	8.13	3.56	5.33
		PW/D	0.056	0.048	0.041	0.024	0.008	0.000	0.030	0.052	0.017	0.025	0.038	0.047
		PW/W	0.273	0.077	0.250	0.176	0.000	0.000	0.238	0.211	0.313	0.318	0.222	0.349
		MEAN	3.81	4.06	2.54	4.32	2.54	0.00	4.06	4.32	8.89	5.84	4.32	4.32
		SDEV	4.32	6.35	2.79	7.62	3.81	0.00	6.35	6.35	17.53	9.40	7.62	4.83
		SKEW	1.16	3.33	2.57	2.41	2.17	0.00	2.57	2.34	2.53	3.02	3.01	1.64
BAKERSFIELD, CALIFORNIA														
LATT= 35.42 LONG= 119.05														
YRS= 32. ELEV.= 475.														
TP5= 25.40 TP6= 53.34														
		TMAX	14.1	17.2	20.7	24.3	29.2	33.4	37.9	36.5	33.2	27.2	20.3	15.0
		TMIN	3.0	5.0	6.9	10.1	13.4	16.7	20.1	18.7	16.2	11.5	6.2	3.6
		CVT	0.10	0.09	0.10	0.09	0.07	0.07	0.04	0.07	0.05	0.06	0.10	0.10
		RAD	238.	326.	474.	549.	642.	700.	678.	645.	640.	433.	264.	207.
		P5MX	5.08	5.08	5.59	3.05	6.60	1.02	0.51	5.59	7.37	15.24	4.57	5.59
		PW/D	0.132	0.132	0.130	0.095	0.039	0.008	0.010	0.006	0.019	0.022	0.082	0.117
		PW/W	0.425	0.482	0.346	0.474	0.297	0.444	0.300	0.250	0.214	0.391	0.364	0.303
		MEAN	4.32	4.57	3.56	4.57	2.54	2.29	1.78	1.27	3.05	6.35	5.84	3.56
		SDEV	4.83	5.33	4.57	5.08	3.81	2.79	2.29	1.78	3.81	6.60	6.35	4.32
		SKEW	1.99	2.25	2.12	1.41	3.52	1.11	1.50	1.98	1.77	2.43	2.18	2.15
BLUE CANYON, CALIFORNIA														
LATT= 39.28 LONG= 120.70														
YRS= 30. ELEV.= 5280.														
TP5= 30.48 TP6= 170.18														
		TMAX	6.4	6.3	7.9	11.7	15.7	19.6	25.0	24.8	22.2	16.8	12.1	8.6
		TMIN	-0.8	-0.7	0.4	3.3	6.7	10.6	15.0	13.8	12.2	7.4	3.1	0.6
		CVT	0.23	0.24	0.20	0.16	0.15	0.12	0.08	0.15	0.11	0.14	0.17	0.21
		RAD	178.	261.	394.	532.	629.	693.	686.	616.	497.	351.	226.	152.
		P5MX	9.40	6.10	5.59	5.84	6.10	5.08	6.86	9.40	6.86	9.14	6.35	7.11
		PW/D	0.203	0.213	0.231	0.184	0.155	0.073	0.025	0.032	0.054	0.080	0.200	0.174
		PW/W	0.731	0.678	0.663	0.631	0.556	0.488	0.057	0.296	0.370	0.437	0.628	0.710
		MEAN	28.96	21.59	17.78	14.22	9.40	6.60	1.78	6.86	6.86	24.38	21.34	28.70
		SDEV	31.24	24.13	18.03	17.78	13.46	7.37	2.03	15.24	11.68	35.56	21.59	33.02
		SKEW	2.03	1.95	1.44	2.24	5.11	1.35	1.52	3.28	3.93	2.62	1.06	2.53

STA.	ST.	VARIABLE	J	F	M	A	M	J	J	A	S	O	N	D
EUREKA, CALIFORNIA														
LATT= 40.48 LONG= 124.10														
YRS= 59. ELEV.= 43.														
TP5= 26.67 TP6= 137.16														
		TMAX	12.0	12.3	12.5	13.2	14.4	15.6	15.9	16.1	16.4	15.7	14.2	12.8
		TMIN	5.1	5.6	6.0	7.3	8.9	10.5	11.1	11.4	10.6	9.2	7.2	5.9
		CVT	0.12	0.15	0.12	0.11	0.11	0.10	0.08	0.12	0.09	0.10	0.11	0.13
		RAD	149.	249.	346.	498.	599.	675.	700.	614.	452.	300.	174.	99.
		P5MX	13.72	20.57	6.35	4.57	5.59	6.60	1.78	4.32	11.43	9.40	13.21	13.97
		PW/D	0.331	0.265	0.261	0.209	0.167	0.128	0.064	0.058	0.095	0.177	0.272	0.288
		PW/W	0.754	0.693	0.724	0.615	0.518	0.398	0.122	0.305	0.397	0.529	0.691	0.718
		MEAN	11.94	9.65	8.13	7.11	5.59	3.05	1.27	3.56	4.57	8.13	11.43	11.43
		SDEV	12.95	12.95	7.87	9.14	6.86	4.57	1.52	5.10	6.35	9.14	13.46	12.45
		SKEW	2.13	3.75	1.46	2.66	1.88	3.20	2.34	2.06	2.09	2.43	1.71	2.03
FRESNO, CALIFORNIA														
LATT= 36.46 LONG= 119.43														
YRS= 20. ELEV.= 328.														
TP5= 24.89 TP6= 75.69														
		TMAX	13.0	16.3	19.9	24.5	29.2	33.4	37.8	36.4	33.4	27.1	19.7	13.6
		TMIN	2.6	4.2	5.6	8.0	11.0	14.0	17.0	15.6	13.5	9.2	4.4	3.1
		CVT	0.09	0.09	0.11	0.09	0.09	0.06	0.04	0.03	0.06	0.07	0.10	0.11
		RAD	184.	289.	427.	552.	647.	702.	682.	621.	510.	378.	250.	161.
		P5MX	7.87	5.84	6.13	4.57	2.29	2.54	0.51	1.52	4.83	15.76	5.08	10.16
		PW/D	0.172	0.156	0.140	0.105	0.056	0.024	0.010	0.010	0.017	0.034	0.093	0.154
		PW/W	0.509	0.519	0.393	0.477	0.340	0.158	0.160	0.150	0.154	0.286	0.464	0.475
		MEAN	7.11	6.35	6.86	6.86	3.30	2.03	2.03	1.78	4.06	6.35	7.37	6.35
		SDEV	8.89	8.38	7.37	7.37	4.06	2.03	2.29	24.38	4.57	6.35	7.37	7.62
		SKEW	2.43	2.38	1.95	1.36	2.92	1.77	1.80	1.86	1.80	1.20	1.30	1.87
MT.SHASTA, CALIFORNIA														
LATT= 41.32 LONG= 122.32														
YRS= 27. ELEV.= 3544.														
TP5= 30.48 TP6= 101.60														
		TMAX	5.2	8.1	11.2	15.7	19.8	23.8	29.6	29.3	25.8	18.7	11.4	7.0
		TMIN	-3.8	-2.5	-1.0	1.4	4.4	7.6	10.4	9.2	6.9	3.4	-0.6	-2.7
		CVT	0.25	0.23	0.19	0.15	0.13	0.11	0.08	0.12	0.11	0.14	0.18	0.22
		RAD	149.	249.	346.	498.	599.	675.	700.	614.	452.	300.	174.	99.
		P5MX	5.84	6.10	5.08	7.87	4.32	3.81	6.60	5.33	5.08	6.60	7.11	7.62
		PW/D	0.233	0.211	0.206	0.154	0.137	0.101	0.042	0.049	0.049	0.097	0.200	0.185
		PW/W	0.716	0.675	0.645	0.591	0.563	0.466	0.258	0.378	0.386	0.490	0.628	0.689
		MEAN	14.22	12.95	8.64	8.38	6.10	4.57	3.81	4.57	8.64	9.65	14.22	15.24
		SDEV	16.00	17.27	12.45	12.45	7.62	4.57	3.81	5.59	17.27	14.48	17.02	20.83
		SKEW	1.80	2.25	2.86	2.77	2.15	1.86	1.60	2.71	3.65	2.99	1.61	2.26
SAN DIEGO, CALIFORNIA														
LATT= 32.44 LONG= 117.10														
YRS= 29. ELEV.= 13.														
TP5= 31.75 TP6= 88.90														
		TMAX	18.1	18.6	19.3	20.7	21.6	22.6	24.9	25.6	25.3	23.6	22.3	19.4
		TMIN	7.4	8.3	10.1	12.1	13.9	15.4	17.4	18.6	16.8	14.3	10.8	8.4
		CVT	0.11	0.08	0.07	0.06	0.07	0.05	0.04	0.06	0.09	0.10	0.10	0.09
		RAD	244.	302.	397.	457.	506.	487.	497.	464.	389.	320.	277.	221.
		P5MX	16.51	8.64	9.40	7.37	8.38	0.51	1.02	7.87	4.06	3.81	8.64	15.75
		PW/D	0.124	0.131	0.139	0.106	0.047	0.026	0.008	0.010	0.019	0.046	0.103	0.111
		PW/W	0.580	0.388	0.427	0.465	0.396	0.190	0.250	0.333	0.368	0.250	0.479	0.458
		MEAN	6.86	6.60	5.59	4.32	1.78	1.52	1.02	3.56	4.83	3.30	6.35	6.60
		SDEV	9.14	8.38	8.13	5.84	2.54	1.78	1.02	6.35	6.10	5.33	7.87	9.65
		SKEW	2.21	1.86	3.12	2.34	2.35	1.55	1.76	2.63	1.71	2.06	2.35	2.79
SAN FRANCISCO, CALIFORNIA														
LATT= 37.78 LONG= 122.42														
YRS= 33. ELEV.= 52.														
TP5= 31.75 TP6= 101.60														
		TMAX	13.2	14.8	15.9	16.6	17.4	18.3	17.9	18.3	20.5	20.2	17.6	14.2
		TMIN	7.5	8.5	9.2	9.7	10.7	11.7	11.8	12.2	12.8	12.4	10.6	8.6
		CVT	0.12	0.08	0.10	0.10	0.10	0.12	0.09	0.16	0.09	0.09	0.09	0.10
		RAD	150.	250.	350.	532.	592.	660.	672.	602.	451.	320.	224.	124.
		P5MX	13.97	12.95	9.14	10.16	1.52	1.52	4.06	3.81	3.81	12.70	13.97	9.40
		PW/D	0.225	0.193	0.203	0.121	0.063	0.042	0.016	0.030	0.028	0.090	0.163	0.166
		PW/W	0.662	0.602	0.566	0.515	0.429	0.250	0.091	0.238	0.280	0.385	0.587	0.680
		MEAN	10.16	7.37	6.60	6.60	3.81	3.30	0.51	1.52	5.08	6.60	7.62	9.40
		SDEV	11.94	8.13	8.13	8.38	5.84	6.86	0.25	2.79	11.94	11.43	8.38	10.92
		SKEW	2.17	1.79	2.41	2.67	3.13	3.44	0.41	3.37	3.37	2.84	1.24	1.99

TA. ST.	VARIABLE	J	F	M	A	M	J	J	A	S	O	N	D
COLORADO SPRINGS, COLORADO													
LATT= 38.49 LONG= 4.43													
YRS= 19. ELEV.= 145.													
TP5= 46.99 TP6= 85.09													
	TMAX	5.5	7.1	9.6	14.9	20.2	25.8	29.0	28.2	24.4	19.2	10.7	7.1
	TMIN	-9.3	-7.7	-5.1	0.2	5.3	10.5	13.7	13.1	8.4	2.2	-4.7	-7.4
	CVT	0.36	0.36	0.29	0.16	0.13	0.09	0.07	0.11	0.10	0.12	0.13	0.31
	RAD	206.	273.	405.	465.	465.	530.	525.	444.	417.	315.	527.	157.
	P5MX	2.29	0.76	3.81	7.37	18.80	37.59	19.30	50.80	20.07	77.72	4.32	1.02
	PW/D	0.098	0.123	0.173	0.159	0.232	0.235	0.400	0.253	0.140	0.111	0.093	0.087
	PW/W	0.333	0.400	0.467	0.456	0.530	0.487	0.521	0.559	0.423	0.424	0.368	0.329
	MEAN	1.78	1.78	2.54	4.32	5.59	5.84	5.33	5.33	5.59	4.32	3.30	1.78
	SDEV	2.54	2.03	3.05	7.11	8.89	10.67	8.13	7.62	7.37	6.35	3.56	1.78
	SKEW	3.10	2.53	1.89	3.51	3.08	3.83	4.03	4.35	2.16	3.12	2.04	2.00
DENVER, COLORADO													
LATT= 39.77 LONG= 104.88													
YRS= 33. ELEV.= 5283.													
TP5= 45.72 TP6= 82.55													
	TMAX	5.6	7.0	9.9	15.3	21.4	27.8	31.3	30.4	26.1	19.2	10.9	7.3
	TMIN	-9.6	-7.6	-5.1	0.2	5.4	10.6	14.1	13.4	8.3	2.3	-4.7	-7.8
	CVT	0.36	0.35	0.27	0.15	0.10	0.05	0.04	0.11	0.09	0.12	0.21	0.31
	RAD	203.	270.	403.	462.	462.	527.	522.	441.	414.	312.	224.	184.
	P5MX	1.78	3.56	3.30	4.83	6.38	10.41	17.53	31.50	11.68	4.06	3.56	3.05
	PW/D	0.130	0.177	0.201	0.202	0.208	0.246	0.237	0.228	0.149	0.113	0.122	0.126
	PW/W	0.423	0.384	0.503	0.483	0.540	0.443	0.435	0.373	0.419	0.408	0.427	0.394
	MEAN	2.29	3.30	3.56	4.83	7.11	4.83	5.33	4.32	5.08	5.59	3.56	2.29
	SDEV	3.30	4.06	4.57	8.89	11.43	9.40	8.13	7.37	7.11	7.37	3.81	2.54
	SKEW	3.13	2.43	3.05	5.38	2.94	5.05	2.69	3.46	2.21	2.45	1.46	2.09
GRAND JUNCTION, COLORADO													
LATT= 39.07 LONG= 108.32													
YRS= 21. ELEV.= 4855.													
TP5= 32.26 TP6= 57.15													
	TMAX	1.6	5.4	11.6	18.3	24.1	29.9	33.6	31.7	27.3	19.7	9.7	3.4
	TMIN	-8.3	-4.8	-1.0	4.2	9.4	13.7	17.7	16.7	12.4	5.9	-2.2	-6.7
	CVT	0.29	0.20	0.16	0.11	0.10	0.06	0.04	0.10	0.08	0.11	0.16	0.27
	RAD	227.	324.	434.	546.	615.	708.	676.	595.	514.	373.	260.	212.
	P5MX	2.03	2.79	3.05	4.06	3.30	5.08	32.51	7.87	8.36	4.06	3.05	3.05
	PW/D	0.173	0.163	0.179	0.168	0.107	0.036	0.114	0.184	0.136	0.107	0.127	0.169
	PW/W	0.407	0.410	0.388	0.404	0.476	0.427	0.318	0.384	0.391	0.475	0.385	0.344
	MEAN	2.29	2.29	2.29	2.79	3.05	3.30	2.29	3.81	3.81	4.32	3.05	2.54
	SDEV	2.79	2.54	2.79	3.81	3.30	4.57	3.56	4.83	4.57	4.32	3.81	3.81
	SKEW	2.26	2.02	2.68	2.70	1.44	2.92	2.61	2.25	2.25	1.53	2.32	5.02
PUEBLO, COLORADO													
LATT= 38.17 LONG= 104.31													
YRS= 27. ELEV.= 4684.													
TP5= 48.26 TP6= 86.39													
	TMAX	7.4	9.2	12.7	16.8	24.1	30.5	33.4	32.1	28.1	21.6	13.2	9.3
	TMIN	-9.6	-7.1	-3.7	1.9	7.7	12.9	16.0	15.3	10.3	3.7	-4.3	-6.0
	CVT	0.28	0.26	0.26	0.13	0.10	0.06	0.04	0.10	0.08	0.13	0.16	0.27
	RAD	20[illegible].	275.	408.	467.	467.	532.	527.	446.	419.	317.	529.	189.
	P5MX	0.76	1.02	4.83	11.68	19.30	34.29	21.08	30.23	5.08	2.29	2.03	3.05
	PW/D	0.104	0.113	0.136	0.116	0.172	0.180	0.246	0.230	0.143	0.092	0.093	0.071
	PW/W	0.362	0.411	0.455	0.404	0.455	0.417	0.370	0.417	0.301	0.372	0.282	0.435
	MEAN	1.52	1.78	2.54	5.33	5.33	4.06	5.33	5.33	4.06	5.84	3.30	2.03
	SDEV	2.03	1.78	3.05	8.64	8.89	6.10	7.62	9.40	5.84	9.40	3.30	2.29
	SKEW	2.39	2.20	2.24	3.18	3.53	2.87	2.57	3.82	2.19	4.62	1.19	1.30
HARTFORD (WINDSOR LOCKS) CT													
LATT= 41.93 LONG= 72.68													
YRS= 53. ELEV.= 169.													
TP5= 57.15 TP6= 125.73													
	TMAX	2.3	3.3	6.6	15.5	22.4	27.2	29.8	28.3	24.2	18.2	10.9	3.9
	TMIN	-7.8	-7.7	-2.6	2.2	8.3	13.8	16.7	15.5	11.2	5.0	-0.4	-6.6
	CVT	0.39	0.42	0.29	0.18	0.11	0.09	0.06	0.13	0.11	0.14	0.21	0.35
	RAD	154.	219.	300.	354.	456.	512.	525.	450.	350.	238.	166.	124.
	P5MX	7.62	7.11	6.60	14.73	16.00	14.73	36.07	33.02	22.86	36.83	5.59	10.16
	PW/D	0.311	0.311	0.301	0.310	0.309	0.295	0.275	0.274	0.236	0.182	0.297	0.297
	PW/W	0.406	0.454	0.445	0.475	0.412	0.469	0.356	0.387	0.444	0.421	0.513	0.493
	MEAN	7.11	8.13	9.40	8.89	6.86	7.62	8.38	10.92	10.67	11.43	9.14	8.89
	SDEV	8.89	10.67	10.92	11.68	9.14	11.18	11.18	21.08	16.76	16.51	11.68	11.18
	SKEW	2.33	2.04	2.09	2.66	2.49	2.96	2.56	5.82	3.30	3.07	2.42	1.77

STA.	ST.	VARIABLE	J	F	M	A	M	J	J	A	S	O	N	D
BOISE, IDAHO														
LATT= 43.57 LONG= 116.22														
YRS= 31. ELEV.= 2838.														
TP5= 19.05 TP6= 44.45														
		TMAX	2.3	5.8	10.8	17.4	22.2	26.9	33.0	31.5	26.0	18.5	9.1	4.1
		TMIN	-5.5	-3.1	-0.1	3.0	6.9	10.6	15.0	13.1	8.1	3.3	-1.8	-3.9
		CVT	0.37	0.29	0.20	0.15	0.12	0.12	0.08	0.15	0.11	0.14	0.24	0.26
		RAD	138.	236.	342.	485.	585.	636.	670.	578.	460.	301.	182.	124.
		P5MX	2.29	7.11	4.57	4.83	5.33	7.37	7.87	13.97	3.56	4.32	2.29	1.27
		PW/D	0.317	0.235	0.223	0.211	0.196	0.150	0.053	0.083	0.083	0.152	0.213	0.271
		PW/W	0.595	0.559	0.459	0.406	0.476	0.464	0.250	0.353	0.370	0.339	0.534	0.543
		MEAN	3.30	2.79	2.54	3.81	4.06	3.81	2.29	3.56	3.30	3.05	3.56	2.79
		SDEV	4.06	3.30	3.05	4.83	5.08	5.33	4.06	4.83	3.81	2.79	3.56	3.81
		SKEW	2.68	2.82	3.10	2.73	2.14	4.87	4.22	1.86	1.91	1.30	1.42	2.80
POCATELLO, IDAHO														
LATT= 42.55 LONG= 112.36														
YRS= 21. ELEV.= 4454.														
TP5= 25.40 TP6= 49.53														
		TMAX	-0.2	2.5	7.8	15.4	20.7	25.4	32.0	30.8	25.0	17.7	7.4	2.4
		TMIN	-10.6	-7.9	-3.6	0.7	4.9	8.7	12.8	11.5	6.4	1.3	-4.2	-7.5
		CVT	0.42	0.30	0.24	0.14	0.12	0.10	0.07	0.16	0.10	0.14	0.21	0.35
		RAD	162.	239.	354.	461.	551.	591.	601.	539.	431.	285.	175.	130.
		P5MX	2.03	3.05	2.79	3.05	3.56	7.87	12.70	3.81	4.57	13.72	3.05	1.78
		PW/D	0.289	0.253	0.230	0.213	0.194	0.169	0.095	0.107	0.099	0.110	0.134	0.259
		PW/W	0.511	0.524	0.479	0.380	0.505	0.509	0.286	0.360	0.353	0.370	0.450	0.548
		MEAN	2.29	2.03	2.03	3.81	3.30	3.81	2.54	3.56	3.05	3.81	2.79	2.29
		SDEV	3.05	2.54	2.03	3.81	4.57	4.83	3.81	4.83	4.06	4.83	3.30	2.79
		SKEW	3.04	2.38	2.14	1.93	2.93	2.11	3.75	2.24	3.00	3.21	2.43	2.68
BILLINGS, MONTANA														
LATT= 45.80 LONG= 108.53														
YRS= 36. ELEV.= 3567.														
TP5= 34.29 TP6= 68.58														
		TMAX	0.7	2.2	6.3	14.1	20.1	24.4	31.4	29.6	23.1	16.4	7.2	3.7
		TMIN	-10.5	-9.3	-4.4	1.4	7.4	12.3	16.0	14.8	8.5	2.9	-3.8	-7.7
		CVT	0.48	0.45	0.35	0.18	0.14	0.12	0.06	0.13	0.11	0.15	0.34	0.38
		RAD	150.	261.	372.	462.	563.	622.	624.	526.	432.	289.	172.	138.
		P5MX	2.29	2.03	4.06	4.83	11.18	12.45	30.23	11.68	6.10	3.05	7.62	2.54
		PW/D	0.198	0.184	0.241	0.233	0.270	0.314	0.177	0.170	0.165	0.160	0.166	0.139
		PW/W	0.442	0.500	0.439	0.475	0.544	0.491	0.328	0.376	0.414	0.307	0.347	0.439
		MEAN	2.29	2.54	2.79	5.33	4.83	5.33	3.30	4.06	4.57	3.81	3.30	2.54
		SDEV	2.54	2.54	3.56	7.87	7.37	7.62	6.10	5.84	7.11	5.09	5.08	3.30
		SKEW	1.77	1.94	2.76	3.86	4.29	2.84	4.31	4.00	3.91	2.55	3.05	2.29

STA. ST.	VARIABLE	J	F	M	A	M	J	J	A	S	O	N	D
GREAT FALLS, MONTANA LATT= 47.29 LONG= 111.22 YRS= 33. ELEV.= 3662. TP5= 32.26 TP6= 60.96													
	TMAX	-0.2	1.1	5.1	12.9	18.7	22.7	28.3	27.7	21.8	15.2	6.8	2.1
	TMIN	-10.8	-10.2	-6.6	-0.1	4.6	8.3	12.3	11.0	6.4	2.0	-4.2	-7.3
	CVT	0.56	0.45	0.37	0.20	0.14	0.11	0.08	0.15	0.13	0.16	0.32	0.52
	RAD	140.	232.	366.	434.	528.	583.	639.	532.	407.	264.	154.	112.
	P5MX	4.06	2.54	2.29	4.57	5.59	25.15	21.84	13.97	5.59	3.81	3.05	1.78
	PW/D	0.210	0.211	0.207	0.245	0.269	0.297	0.177	0.162	0.119	0.129	0.156	0.178
	PW/W	0.526	0.490	0.478	0.490	0.523	0.564	0.383	0.457	0.425	0.393	0.453	0.461
	MEAN	2.54	2.54	2.54	3.56	5.84	6.35	4.06	4.06	3.81	3.56	3.05	2.29
	SDEV	3.30	3.05	3.05	5.59	9.14	9.14	5.33	5.59	4.83	4.06	3.56	2.29
	SKEW	2.41	2.73	2.90	4.99	3.24	3.07	1.98	2.38	2.20	2.12	2.03	1.31
HAVRE, MONTANA LATT= 48.33 LONG= 109.46 YRS= 10. ELEV.= 2584. TP5= 32.26 TP6= 67.31													
	TMAX	-4.3	-2.6	3.2	13.6	20.3	23.2	29.8	28.1	21.3	15.2	4.6	-0.4
	TMIN	-15.8	-14.9	-8.9	-1.3	4.8	9.0	12.6	10.8	4.8	0.2	-7.7	-11.9
	CVT	1.25	0.85	0.50	0.32	0.14	0.13	0.09	0.25	0.15	0.20	0.43	0.80
	RAD	135.	227.	361.	429.	523.	578.	634.	527.	402.	259.	149.	107.
	P5MX	1.02	2.54	3.05	3.05	14.73	10.41	11.68	12.70	2.79	7.62	1.78	2.03
	PW/D	0.139	0.162	0.169	0.183	0.237	0.302	0.154	0.152	0.163	0.138	0.130	0.144
	PW/W	0.503	0.481	0.317	0.449	0.457	0.500	0.433	0.424	0.433	0.273	0.394	0.453
	MEAN	1.52	1.52	1.78	4.06	4.32	5.33	5.33	4.57	4.06	3.30	2.29	1.78
	SDEV	1.78	1.27	2.03	5.08	6.35	6.35	6.60	7.62	5.08	4.32	3.05	2.03
	SKEW	2.64	1.30	2.95	2.63	2.91	3.32	1.91	4.18	2.20	2.18	2.30	2.45
HELENA, MONTANA LATT= 46.36 LONG= 112.00 YRS= 30. ELEV.= 3828. TP5= 30.48 TP6= 57.15													
	TMAX	-1.8	0.9	5.8	13.4	18.8	22.4	29.1	27.9	21.6	14.9	5.8	1.2
	TMIN	-13.1	-10.7	-6.6	-0.8	4.4	8.1	11.3	10.1	5.1	0.2	-6.2	-9.9
	CVT	0.61	0.36	0.35	0.17	0.13	0.10	0.08	0.14	0.14	0.16	0.27	0.52
	RAD	142.	234.	368.	436.	530.	585.	641.	534.	409.	266.	156.	114.
	P5MX	1.78	2.03	2.03	3.56	4.83	30.73	16.00	10.67	6.35	1.78	1.52	2.03
	PW/D	0.215	0.184	0.200	0.249	0.260	0.286	0.180	0.207	0.147	0.159	0.125	0.183
	PW/W	0.429	0.328	0.421	0.373	0.498	0.573	0.381	0.361	0.446	0.331	0.390	0.481
	MEAN	1.78	1.78	2.29	3.05	4.32	4.83	3.30	3.56	3.05	2.79	2.03	1.78
	SDEV	2.03	2.29	2.79	4.06	6.86	5.59	4.06	4.32	4.32	3.81	2.79	1.78
	SKEW	2.55	2.79	1.99	2.74	4.01	2.05	2.48	2.07	2.84	2.40	2.64	1.31
KALISPELL, MONTANA LATT= 48.18 LONG= 114.16 YRS= 21. ELEV.= 2965. TP5= 22.10 TP6= 54.61													
	TMAX	-2.4	1.1	5.7	13.6	19.1	22.5	28.7	27.3	21.2	13.3	4.1	-0.4
	TMIN	-11.1	-9.5	-5.9	-0.6	3.3	7.1	8.7	7.2	4.0	-0.2	-5.2	-7.4
	CVT	0.51	0.41	0.42	0.16	0.12	0.10	0.09	0.18	0.15	0.16	0.41	0.52
	RAD	135.	227.	361.	429.	523.	578.	634.	527.	402.	259.	149.	107.
	P5MX	2.03	1.78	3.56	4.06	7.62	14.48	8.64	30.48	10.16	2.54	2.03	2.54
	PW/D	0.383	0.309	0.249	0.250	0.264	0.310	0.145	0.164	0.197	0.217	0.322	0.431
	PW/W	0.656	0.567	0.539	0.429	0.516	0.583	0.310	0.510	0.525	0.540	0.525	0.570
	MEAN	2.54	2.03	1.78	2.79	4.06	5.08	3.81	4.32	3.56	2.79	2.79	2.54
	SDEV	2.79	2.54	2.29	4.32	5.33	6.60	4.83	5.59	4.57	3.05	3.56	3.30
	SKEW	2.03	2.49	2.63	4.53	3.04	2.68	2.18	2.28	2.57	1.64	2.03	3.62
MILES CITY, MONTANA LATT= 46.26 LONG= 105.52 YRS= 33. ELEV.= 2629. TP5= 43.94 TP6= 81.28													
	TMAX	-2.6	-0.1	5.7	14.8	21.4	25.8	32.3	30.8	24.0	16.9	6.4	0.9
	TMIN	-14.7	-12.9	-7.0	0.4	6.7	11.4	15.6	14.3	8.2	1.9	-5.7	-10.7
	CVT	0.75	0.64	0.46	0.21	0.16	0.11	0.08	0.16	0.14	0.19	0.38	0.55
	RAD	140.	232.	366.	434.	528.	583.	639.	532.	407.	264.	154.	112.
	P5MX	1.02	2.54	3.05	3.05	14.73	10.41	11.68	12.70	2.79	7.62	1.78	2.03
	PW/D	0.212	0.193	0.200	0.213	0.262	0.309	0.230	0.166	0.146	0.135	0.153	0.163
	PW/W	0.444	0.467	0.385	0.488	0.507	0.491	0.344	0.386	0.460	0.324	0.355	0.497
	MEAN	1.52	2.03	2.03	4.06	5.08	6.60	5.08	4.32	3.81	2.54	2.54	1.78
	SDEV	1.78	2.54	2.29	5.08	7.37	9.14	7.37	6.10	5.59	4.32	3.81	1.78
	SKEW	2.05	3.46	2.01	2.42	3.20	3.18	2.33	2.92	3.52	5.02	4.33	1.61

APPENDIX I

STA. ST. VARIABLE	J	F	M	A	M	J	J	A	S	O	N	D

RENO, NEVADA
LATT= 39.30 LONG= 119.47
YRS= 16. ELEV.= 4397.
TP5= 22.86 TP6= 63.50

VARIABLE	J	F	M	A	M	J	J	A	S	O	N	D
TMAX	7.6	10.5	13.6	18.7	22.9	27.1	33.2	32.3	27.9	21.2	13.9	8.4
TMIN	-6.6	-5.8	-4.1	-0.9	2.9	5.6	8.5	7.1	3.7	-0.4	-4.8	-7.2
CVT	0.31	0.24	0.20	0.14	0.12	0.10	0.08	0.12	0.10	0.12	0.16	0.24
RAD	223.	316.	374.	551.	615.	691.	780.	681.	510.	357.	248.	192.
P5MX	4.06	3.05	2.79	1.78	3.05	2.03	5.84	9.40	3.05	3.81	3.05	4.06
PW/D	0.136	0.113	0.135	0.101	0.101	0.074	0.067	0.049	0.044	0.046	0.093	0.136
PW/W	0.490	0.454	0.380	0.349	0.414	0.386	0.294	0.420	0.297	0.250	0.500	0.484
MEAN	5.08	4.83	3.30	3.30	4.32	3.30	2.54	2.54	3.81	4.32	3.56	4.83
SDEV	6.60	6.60	4.06	5.84	5.84	3.56	2.54	3.81	3.56	7.11	4.06	7.11
SKEW	2.51	2.77	2.11	4.18	2.33	1.57	1.29	3.92	0.78	3.43	1.77	3.34

WINNEMUCCA, NEVADA
LATT= 40.54 LONG= 117.48
YRS= 67. ELEV.= 4299.
TP5= 19.05 TP6= 36.83

VARIABLE	J	F	M	A	M	J	J	A	S	O	N	D
TMAX	3.0	6.7	10.3	16.3	21.6	26.7	33.3	31.3	25.2	18.1	10.2	4.2
TMIN	-7.7	-3.9	-2.1	0.1	4.7	8.6	13.6	10.6	5.8	0.4	-3.9	-6.4
CVT	0.43	0.33	0.24	0.16	0.15	0.11	0.09	0.13	0.12	0.15	0.23	0.39
RAD	236.	339.	468.	563.	625.	712.	647.	618.	518.	394.	289.	216.
P5MX	3.30	2.79	2.54	4.57	5.33	8.64	3.05	6.13	4.83	6.86	2.54	3.30
PW/D	0.198	0.177	0.153	0.146	0.147	0.113	0.053	0.052	0.058	0.087	0.149	0.193
PW/W	0.467	0.426	0.443	0.351	0.448	0.554	0.243	0.289	0.340	0.385	0.498	0.473
MEAN	2.79	2.79	2.29	3.56	3.05	4.06	2.03	3.81	2.79	3.56	3.05	2.79
SDEV	3.05	3.30	2.54	4.32	3.56	5.59	2.79	4.57	3.81	5.33	3.30	3.30
SKEW	1.64	2.16	2.11	1.77	1.37	2.67	1.86	1.86	2.31	4.53	2.07	2.70

KO, NEVADA
LATT= 40.50 LONG= 115.47
YRS= 27. ELEV.= 5075.
TP5= 19.05 TP6= 40.64

VARIABLE	J	F	M	A	M	J	J	A	S	O	N	D
TMAX	1.4	4.6	9.6	15.8	21.4	26.1	32.9	31.7	26.3	18.8	9.5	3.8
TMIN	-12.7	-8.6	-5.1	-1.8	1.9	5.3	9.5	7.8	2.4	-1.7	-6.8	-9.5
CVT	0.57	0.47	0.25	0.19	0.13	0.11	0.07	0.15	0.13	0.14	0.28	0.48
RAD	236.	339.	468.	563.	625.	712.	647.	618.	518.	394.	289.	216.
P5MX	2.03	2.29	3.05	4.57	3.05	7.62	11.68	2.54	8.89	3.05	2.54	2.54
PW/D	0.224	0.216	0.212	0.163	0.176	0.130	0.095	0.091	0.083	0.080	0.146	0.220
PW/W	0.467	0.533	0.420	0.476	0.532	0.547	0.310	0.354	0.250	0.338	0.496	0.489
MEAN	3.30	2.03	2.54	2.54	2.79	3.81	2.29	4.57	2.54	3.56	3.05	3.05
SDEV	4.57	2.79	3.05	3.30	3.30	5.08	3.30	12.45	4.32	4.83	3.30	3.56
SKEW	2.97	2.56	1.90	2.64	2.12	2.30	2.46	7.07	4.84	2.25	1.80	2.09

LAS VEGAS, NEVADA
LATT= 36.08 LONG= 115.17
YRS= 21. ELEV.= 2162.
TP5= 26.67 TP6= 51.05

VARIABLE	J	F	M	A	M	J	J	A	S	O	N	D
TMAX	13.0	16.7	20.5	25.9	31.1	37.2	40.8	39.6	35.7	27.6	19.5	14.5
TMIN	0.6	3.7	6.7	11.4	15.7	20.1	24.2	23.1	18.4	11.7	4.9	1.9
CVT	0.17	0.14	0.13	0.11	0.10	0.08	0.06	0.11	0.08	0.10	0.13	0.15
RAD	277.	384.	519.	621.	702.	746.	675.	627.	551.	429.	318.	253.
P5MX	3.05	6.35	5.08	2.54	7.37	0.76	24.13	16.00	12.70	7.37	2.03	3.56
PW/D	0.061	0.065	0.055	0.048	0.025	0.022	0.067	0.082	0.040	0.041	0.056	0.047
PW/W	0.271	0.311	0.346	0.250	0.211	0.071	0.275	0.161	0.258	0.300	0.333	0.356
MEAN	4.06	3.05	3.05	3.56	2.79	4.06	4.57	4.83	5.05	3.05	5.84	3.30
SDEV	4.57	3.05	4.06	5.08	3.81	5.33	7.37	10.16	7.11	4.06	7.87	4.57
SKEW	1.54	1.53	2.29	2.66	2.04	1.93	2.93	4.59	2.07	1.80	1.63	2.50

STA.	ST.	VARIABLE	J	F	M	A	M	J	J	A	S	O	N	D
ALBUQERQUE, NEW MEXICO														
LATT= 35.05 LONG= 106.62														
YRS= 32. ELEV.= 5311.														
TP5= 37.59 TP6= 77.47														
		TMAX	8.0	11.2	14.9	20.6	25.7	31.4	32.9	31.1	27.9	21.5	13.4	9.1
		TMIN	-4.7	-2.5	0.4	5.7	11.1	16.2	18.8	17.9	14.2	7.4	-0.3	-3.6
		CVT	0.29	0.19	0.16	0.11	0.10	0.07	0.05	0.05	0.07	0.10	0.13	0.15
		RAD	303.	386.	511.	618.	686.	726.	683.	626.	554.	439.	334.	276.
		P5MX	4.32	2.29	3.05	7.62	12.70	24.89	12.95	14.48	9.14	17.53	3.05	4.06
		PW/D	0.080	0.080	0.095	0.073	0.094	0.077	0.253	0.240	0.129	0.090	0.070	0.093
		PW/W	0.263	0.392	0.346	0.264	0.346	0.412	0.395	0.429	0.320	0.378	0.339	0.350
		MEAN	2.29	2.54	3.05	3.81	2.54	3.81	4.06	3.81	3.81	5.59	2.79	3.30
		SDEV	3.81	2.29	3.30	6.35	3.56	6.35	5.59	5.08	6.10	7.62	3.05	4.06
		SKEW	3.50	1.31	2.13	4.49	2.28	3.67	2.92	2.45	4.74	2.77	2.06	2.05
ROSWELL, NEW MEXICO														
LATT= 33.24 LONG= 104.32														
YRS= 24. ELEV.= 3612.														
TP5= 52.07 TP6= 92.71														
		TMAX	12.8	15.6	20.4	26.1	30.4	35.3	35.2	34.1	30.6	24.9	18.3	13.8
		TMIN	-6.3	-4.6	-1.1	3.9	9.6	14.8	16.5	15.4	11.3	5.1	-2.9	-6.1
		CVT	0.22	0.22	0.16	0.10	0.08	0.07	0.05	0.07	0.08	0.10	0.15	0.22
		RAD	313.	410.	527.	634.	694.	709.	646.	620.	556.	440.	352.	293.
		P5MX	1.52	2.29	2.79	7.37	32.00	26.67	45.72	49.28	23.37	19.56	5.84	1.02
		PW/D	0.063	0.097	0.072	0.056	0.091	0.117	0.197	0.173	0.125	0.078	0.053	0.070
		PW/W	0.314	0.352	0.356	0.286	0.329	0.307	0.406	0.421	0.384	0.531	0.360	0.369
		MEAN	4.06	3.56	3.56	4.32	4.57	5.08	5.59	5.84	5.59	6.60	3.56	3.56
		SDEV	5.33	4.06	5.33	6.10	8.38	7.37	8.64	8.13	9.91	11.94	4.83	4.83
		SKEW	2.40	1.67	2.91	2.91	5.00	2.21	3.76	2.45	3.08	3.47	2.72	2.46
BURNS, OREGON														
LATT= 43.35 LONG= 119.03														
YRS= 21. ELEV.= 4140.														
TP5= 21.59 TP6= 38.10														
		TMAX	1.9	5.5	10.8	16.1	20.7	24.3	30.7	29.4	24.5	17.6	9.6	3.4
		TMIN	-11.0	-6.4	-3.2	0.1	3.8	7.4	11.2	9.7	4.7	-0.7	-4.7	-8.3
		CVT	0.41	0.33	0.22	0.16	0.14	0.10	0.08	0.15	0.11	0.14	0.26	0.27
		RAD	138.	236.	342.	485.	585.	636.	670.	576.	460.	301.	182.	124.
		P5MX	3.05	1.78	3.81	5.08	4.57	5.08	7.11	4.06	2.54	2.79	2.03	2.03
		PW/D	0.353	0.223	0.233	0.178	0.180	0.157	0.067	0.082	0.072	0.127	0.201	0.243
		PW/W	0.566	0.519	0.545	0.438	0.468	0.433	0.255	0.352	0.339	0.508	0.598	0.606
		MEAN	3.56	3.30	2.54	2.54	3.05	3.30	3.30	3.30	4.32	3.81	3.81	3.81
		SDEV	4.32	3.81	2.54	3.05	3.56	3.81	5.08	4.83	6.35	5.33	4.32	4.83
		SKEW	2.47	2.05	2.56	2.12	2.04	1.83	3.58	2.39	2.24	2.48	2.53	3.52
MEACHUM, OREGON														
LATT= 45.30 LONG= 118.24														
YRS= 13. ELEV.= 4050.														
TP5= 25.40 TP6= 27.69														
		TMAX	0.0	2.3	5.5	10.5	14.9	18.7	25.2	24.6	19.8	13.1	5.5	1.7
		TMIN	-7.9	-5.7	-3.3	-0.4	2.8	5.8	9.4	9.4	6.5	1.9	-2.6	-4.9
		CVT	0.39	0.36	0.28	0.18	0.17	0.12	0.09	0.17	0.14	0.17	0.32	0.23
		RAD	117.	222.	351.	521.	616.	660.	707.	604.	458.	274.	138.	100.
		P5MX	3.56	2.79	2.03	6.60	1.02	3.56	17.78	0.51	3.56	2.54	5.33	3.30
		PW/D	0.434	0.331	0.311	0.291	0.270	0.216	0.060	0.100	0.129	0.194	0.298	0.371
		PW/W	0.737	0.729	0.713	0.663	0.610	0.556	0.292	0.536	0.521	0.633	0.721	0.716
		MEAN	6.10	5.33	4.57	4.83	4.57	5.08	3.56	4.83	6.10	6.35	6.35	6.60
		SDEV	7.62	5.59	4.83	5.84	4.83	5.64	4.83	6.10	6.86	7.62	7.62	8.38
		SKEW	2.37	1.67	2.24	2.35	1.78	2.13	2.52	1.74	1.77	2.39	2.53	2.84
MEDFORD, OREGON														
LATT= 42.22 LONG= 122.52														
YRS= 28. ELEV.= 1312.														
TP5= 26.67 TP6= 76.20														
		TMAX	7.0	11.1	15.1	18.7	22.9	26.6	31.6	31.5	27.6	20.2	12.3	7.3
		TMIN	-1.2	0.7	1.8	3.6	6.8	9.9	12.6	11.9	8.4	4.7	1.2	-0.1
		CVT	0.25	0.19	0.16	0.14	0.12	0.11	0.09	0.12	0.10	0.15	0.15	0.21
		RAD	116.	215.	336.	482.	592.	652.	698.	605.	447.	279.	149.	93.
		P5MX	3.81	4.57	5.59	9.91	12.45	7.37	4.83	9.91	7.62	4.32	4.06	6.86
		PW/D	0.361	0.269	0.236	0.129	0.174	0.111	0.036	0.053	0.086	0.159	0.273	0.281
		PW/W	0.655	0.557	0.588	0.534	0.538	0.452	0.344	0.367	0.316	0.529	0.627	0.657
		MEAN	6.10	5.33	3.81	2.79	3.81	3.56	4.32	3.81	4.57	5.84	6.10	7.11
		SDEV	8.38	8.38	4.57	3.30	5.59	3.81	6.86	3.56	6.10	8.38	8.89	10.41
		SKEW	2.37	2.56	2.35	2.87	3.73	2.11	2.21	1.13	2.45	2.71	3.20	3.78

STA. ST.	VARIABLE	J	F	M	A	M	J	J	A	S	O	N	D
PORTLAND, OREGON													
LATT= 45.53 LONG= 122.67													
YRS= 55. ELEV.= 30.													
TP5= 25.40 TP6= 104.14													
	TMAX	6.8	9.7	13.1	16.8	20.3	22.8	26.2	26.0	23.0	17.5	11.5	8.2
	TMIN	1.5	3.2	5.1	7.2	9.8	12.4	14.3	14.4	12.4	9.3	5.4	3.3
	CVT	0.19	0.18	0.15	0.13	0.11	0.10	0.10	0.13	0.11	0.13	0.15	0.19
	RAD	92.	164.	272.	377.	494.	471.	541.	433.	356.	211.	113.	81.
	P5MX	7.87	9.14	4.32	5.59	10.41	11.18	9.40	9.65	6.35	6.10	5.59	6.10
	PW/D	0.425	0.357	0.344	0.309	0.236	0.188	0.071	0.082	0.172	0.232	0.324	0.443
	PW/W	0.802	0.697	0.725	0.634	0.619	0.561	0.336	0.585	0.497	0.654	0.775	0.752
	MEAN	7.87	6.35	5.33	4.32	4.32	4.57	2.79	4.83	4.83	6.60	7.62	7.87
	SDEV	8.89	7.62	5.59	4.83	5.08	5.33	4.06	5.84	6.60	7.11	8.64	6.38
	SKEW	1.89	1.97	1.85	2.28	2.50	2.98	2.92	2.50	4.11	2.11	2.18	1.97
SALEM, OREGON													
LATT= 44.55 LONG= 123.01													
YRS= 20. ELEV.= 195.													
TP5= 26.16 TP6= 106.68													
	TMAX	7.1	10.2	13.3	16.8	20.9	24.6	28.4	27.9	24.7	18.1	11.6	8.3
	TMIN	-0.1	1.7	3.1	4.7	7.1	9.7	11.2	10.9	9.1	6.6	3.3	1.7
	CVT	0.26	0.22	0.14	0.13	0.13	0.11	0.09	0.14	0.10	0.13	0.17	0.14
	RAD	89.	135.	287.	406.	517.	570.	676.	558.	397.	235.	144.	80.
	P5MX	6.35	6.10	6.86	4.32	9.65	8.38	5.59	5.84	6.10	6.35	7.37	6.86
	PW/D	0.411	0.341	0.293	0.304	0.215	0.151	0.045	0.086	0.148	0.233	0.339	0.427
	PW/W	0.791	0.728	0.750	0.636	0.611	0.555	0.404	0.494	0.507	0.659	0.776	0.775
	MEAN	9.65	7.37	6.60	4.32	4.32	4.32	3.05	3.30	5.33	7.37	8.13	9.14
	SDEV	10.67	9.65	7.37	5.08	5.08	5.59	4.06	4.57	7.37	8.64	9.14	10.16
	SKEW	1.85	2.55	2.37	2.53	2.71	2.16	2.71	3.07	2.52	2.57	2.23	2.06
SEXTON SUMMIT, OREGON													
LATT= 42.37 LONG= 123.22													
YRS= 16. ELEV.= 1336.													
TP5= 30.48 TP6= 127.00													
	TMAX	5.3	5.8	8.4	12.4	16.6	19.9	24.7	25.0	21.5	14.9	8.4	5.7
	TMIN	-1.1	-0.9	-0.4	1.2	3.9	6.8	10.0	10.2	9.4	5.4	1.8	-0.5
	CVT	0.20	0.21	0.18	0.16	0.12	0.12	0.10	0.15	0.13	0.16	0.21	0.17
	RAD	116.	215.	336.	482.	592.	652.	698.	605.	447.	279.	149.	93.
	P5MX	5.59	3.56	21.59	5.08	7.11	48.51	4.83	15.75	10.92	7.62	7.11	6.60
	PW/D	0.373	0.312	0.310	0.230	0.179	0.126	0.044	0.053	0.101	0.174	0.276	0.286
	PW/W	0.774	0.669	0.712	0.604	0.602	0.476	0.212	0.426	0.489	0.632	0.719	0.745
	MEAN	9.91	7.87	5.84	4.83	5.59	4.32	3.56	5.08	5.84	8.13	10.16	10.41
	SDEV	12.70	10.92	6.60	6.10	8.64	5.08	5.59	5.84	7.62	10.16	15.24	13.97
	SKEW	2.40	3.10	1.87	3.07	4.39	2.94	3.77	1.71	2.51	2.08	3.31	3.10
HURON, SOUTH DAKOTA													
LATT= 44.23 LONG= 98.13													
YRS= 18. ELEV.= 1282.													
TP5= 62.99 TP6= 106.68													
	TMAX	-4.0	-2.0	6.2	15.3	22.0	27.2	31.9	30.6	25.1	17.8	6.6	-1.0
	TMIN	-16.6	-14.1	-6.5	0.7	6.9	13.0	16.3	14.6	9.1	2.1	-6.1	-12.8
	CVT	0.95	0.67	0.46	0.20	0.15	0.12	0.10	0.19	0.14	0.19	0.35	0.65
	RAD	173.	267.	390.	472.	522.	575.	580.	531.	425.	305.	194.	148.
	P5MX	1.52	4.32	4.57	13.46	12.19	11.94	19.30	16.51	16.26	16.51	5.59	1.02
	PW/D	0.171	0.167	0.189	0.252	0.263	0.324	0.261	0.254	0.176	0.114	0.134	0.169
	PW/W	0.333	0.445	0.379	0.457	0.485	0.465	0.355	0.360	0.368	0.433	0.368	0.331
	MEAN	1.52	3.30	3.30	5.08	6.60	8.64	6.60	6.10	5.84	6.60	3.05	2.54
	SDEV	2.29	5.84	5.33	7.87	9.91	13.72	9.40	11.68	7.11	10.41	5.33	3.81
	SKEW	5.78	4.69	2.84	3.28	2.64	4.63	2.45	4.87	1.79	3.70	3.21	3.02
RAPID CITY, SOUTH DAKOTA													
LATT= 34.03 LONG= 3.05													
YRS= 15. ELEV.= 165.													
TP5= 53.34 TP6= 90.17													
	TMAX	0.6	2.0	5.8	13.7	19.2	24.2	29.9	29.2	23.4	16.6	8.2	2.9
	TMIN	-12.7	-11.0	-6.6	0.2	5.9	10.9	14.9	14.0	8.2	2.4	-4.6	-9.9
	CVT	0.54	0.51	0.42	0.22	0.16	0.13	0.10	0.18	0.14	0.19	0.34	0.44
	RAD	183.	277.	400.	482.	532.	585.	590.	541.	435.	315.	204.	158.
	P5MX	1.27	1.27	3.81	6.35	8.89	22.86	30.23	26.16	6.10	20.32	1.78	1.52
	PW/D	0.156	0.200	0.222	0.233	0.305	0.317	0.239	0.203	0.167	0.103	0.157	0.155
	PW/W	0.370	0.503	0.444	0.518	0.519	0.557	0.394	0.338	0.362	0.360	0.332	0.411
	MEAN	1.52	2.29	2.79	5.08	5.84	6.86	6.10	4.83	4.57	4.06	2.03	1.78
	SDEV	1.78	2.79	4.32	7.11	9.14	9.91	9.14	5.59	7.37	5.59	3.05	1.78
	SKEW	2.39	3.56	4.34	3.09	3.79	3.79	2.54	1.76	4.31	2.93	2.93	2.60

STA.	ST.	VARIABLE	J	F	M	A	M	J	J	A	S	O	N	D
SALT LAKE CITY, UTAH														
LATT= 40.76 LONG= 111.97														
YRS= 29. ELEV.= 4220.														
TP5= 21.59 TP6= 57.15														
		TMAX	2.2	5.9	11.1	17.1	22.7	28.0	33.5	32.1	26.3	19.2	10.1	4.5
		TMIN	-8.3	-4.3	-1.0	3.0	7.1	11.0	16.0	15.1	9.4	4.0	-1.9	-5.1
		CVT	0.39	0.39	0.20	0.15	0.11	0.09	0.07	0.12	0.09	0.13	0.28	0.35
		RAD	163.	256.	354.	479.	570.	621.	620.	551.	446.	316.	204.	146.
		P5MX	4.32	3.81	5.59	6.60	4.83	4.83	7.87	12.19	15.75	6.10	3.81	2.79
		PW/D	0.226	0.263	0.236	0.239	0.165	0.139	0.104	0.139	0.111	0.108	0.170	0.230
		PW/W	0.479	0.397	0.463	0.525	0.467	0.500	0.315	0.373	0.389	0.461	0.434	0.497
		MEAN	3.56	3.81	4.06	5.59	4.57	4.57	4.83	4.32	3.81	4.83	4.32	3.61
		SDEV	4.32	4.57	4.57	6.86	5.33	5.84	8.38	7.11	6.86	5.84	5.33	4.57
		SKEW	2.89	2.18	1.76	2.22	2.23	2.00	4.01	7.85	5.05	2.20	1.89	2.31
MILFORD, UTAH														
LATT= 38.26 LONG= 113.01														
YRS= 9. ELEV.= 5028.														
TP5= 26.16 TP6= 50.80														
		TMAX	2.2	6.0	11.9	17.6	23.2	28.8	33.6	31.9	27.1	19.6	11.7	4.8
		TMIN	-11.4	-7.3	-3.9	-0.1	4.3	8.7	13.1	12.2	6.9	0.4	-5.8	-9.3
		CVT	0.54	0.44	0.24	0.16	0.11	0.10	0.06	0.16	0.10	0.14	0.23	0.36
		RAD	236.	333.	468.	563.	625.	712.	647.	618.	518.	394.	289.	218.
		P5MX	3.30	3.56	3.56	4.06	7.37	4.57	9.65	10.67	5.59	5.08	4.32	2.29
		PW/D	0.151	0.200	0.156	0.153	0.099	0.079	0.119	0.147	0.100	0.078	0.111	0.131
		PW/W	0.364	0.400	0.497	0.442	0.412	0.403	0.344	0.392	0.313	0.408	0.364	0.441
		MEAN	2.79	2.54	3.30	3.81	3.30	3.56	3.05	2.54	4.83	3.81	3.81	2.79
		SDEV	3.56	3.05	4.06	4.32	3.56	4.57	4.32	3.56	7.37	5.08	4.06	3.30
		SKEW	2.86	2.30	2.61	2.06	1.78	2.25	2.21	2.66	2.64	3.05	1.59	3.14
CHEYENNE, WYOMING														
LATT= 41.15 LONG= 104.82														
YRS= 22. ELEV.= 6131.														
TP5= 44.45 TP6= 81.28														
		TMAX	2.8	4.3	6.5	11.9	17.1	23.3	28.1	27.2	22.1	15.4	8.3	4.6
		TMIN	-10.1	-9.1	-6.7	-1.8	2.9	8.1	12.0	11.4	6.2	0.5	-4.9	-8.3
		CVT	0.44	0.49	0.37	0.24	0.16	0.13	0.08	0.13	0.12	0.19	0.29	0.36
		RAD	217.	296.	425.	509.	555.	644.	607.	537.	439.	325.	230.	187.
		P5MX	1.52	1.27	2.54	4.06	8.64	19.81	20.83	18.54	50.80	1.52	2.03	2.03
		PW/D	0.125	0.176	0.225	0.206	0.251	0.282	0.293	0.255	0.159	0.123	0.133	0.131
		PW/W	0.360	0.414	0.489	0.527	0.597	0.488	0.425	0.373	0.444	0.386	0.393	0.343
		MEAN	1.52	1.78	2.54	3.56	5.33	5.33	4.06	4.06	4.06	3.81	2.03	1.52
		SDEV	2.03	3.56	3.81	5.08	6.86	7.87	5.84	5.33	5.59	5.08	2.79	2.29
		SKEW	2.35	8.97	3.61	3.87	2.21	3.27	3.03	2.31	2.78	2.74	3.07	3.32
OLYMPIA, WASHINGTON														
LATT= 46.58 LONG= 122.54														
YRS= 23. ELEV.= 190.														
TP5= 26.67 TP6= 104.14														
		TMAX	7.3	9.8	12.4	16.8	20.3	22.6	26.5	26.1	22.6	16.8	11.3	8.6
		TMIN	-0.5	0.1	1.1	3.1	5.3	7.5	8.9	8.8	6.9	4.7	1.8	1.1
		CVT	0.18	0.17	0.14	0.11	0.11	0.08	0.09	0.14	0.09	0.11	0.12	0.17
		RAD	85.	167.	257.	432.	509.	487.	466.	436.	321.	205.	122.	77.
		P5MX	4.57	5.33	3.56	6.10	12.70	14.22	9.65	10.41	8.64	7.62	9.14	7.11
		PW/D	0.452	0.344	0.321	0.276	0.185	0.194	0.079	0.106	0.160	0.267	0.349	0.455
		PW/W	0.816	0.766	0.753	0.698	0.586	0.542	0.489	0.571	0.601	0.707	0.737	0.738
		MEAN	10.41	8.64	6.60	5.59	4.32	4.06	3.81	5.08	6.35	9.14	10.67	9.91
		SDEV	11.18	10.67	6.86	6.86	4.57	5.08	4.32	6.10	7.37	9.40	13.46	11.43
		SKEW	1.73	3.01	1.88	3.20	2.02	2.77	1.91	1.89	1.91	1.61	2.90	2.36
SPOKANE, WASHINGTON														
LATT= 47.62 LONG= 117.52														
YRS= 17. ELEV.= 2357.														
TP5= 19.05 TP6= 48.26														
		TMAX	-0.3	3.0	8.3	14.8	20.7	23.6	29.8	28.3	23.7	15.6	6.1	2.2
		TMIN	-7.1	-5.3	-1.6	2.2	6.2	9.6	13.0	11.6	8.3	3.3	-1.9	-4.3
		CVT	0.34	0.23	0.23	0.12	0.09	0.11	0.08	0.20	0.09	0.14	0.22	0.34
		RAD	119.	204.	321.	474.	563.	595.	665.	556.	404.	225.	131.	75.
		P5MX	2.03	3.30	2.29	2.54	12.19	8.38	12.95	6.35	11.94	4.57	2.79	3.30
		PW/D	0.361	0.269	0.239	0.225	0.202	0.200	0.039	0.121	0.154	0.184	0.278	0.386
		PW/W	0.648	0.600	0.542	0.409	0.469	0.400	0.240	0.388	0.395	0.479	0.584	0.621
		MEAN	4.32	3.56	3.30	3.30	3.56	4.32	3.05	3.30	2.79	3.81	4.57	4.06
		SDEV	4.57	3.56	3.56	3.56	4.32	6.35	3.56	4.57	3.56	4.57	5.33	4.57
		SKEW	1.88	1.42	1.73	2.30	2.26	2.94	1.83	2.53	2.18	2.10	2.27	2.23

Information Input at Each Read Statement	Format	Number of Cards	Variables	Definitions	Units	Typical Range	Where Information Is Obtained
1. Title	20A4	3	TITLE				User supplied
2. Program control codes	20I4	1	NBYR	Number years of runoff simulation		1-100	User specified
			IYR	Beginning year of runoff simulation		1-2000	•
			LU	Number of sub-areas in basin		1-5	•
			NS	Number of soil layers		1-10	•
			IPC	Print code--0=monthly, 1=daily, 2=yearly		0-2	•
			NSIH	Code for rainfall input--1=measured single, 2=simulated single, 3=measured multiple, 4=simulated multiple		1-4	•
			HSIH	Code for temperature input--1=measured maximum and minimum temperature, 2=simulated single temperatures for entire basin, 3=simulated maximum and minimum temperature for each sub-basin		0-2	•
			IGN	Number of times random number generator cycles before simulation begins		0-100	•
			IHYD	Code for daily basin hydrograph printout--0=print, 1=no print		0-1	•
			IPK	Code for peak-flow calculation--0=route		0-1	•
3. General data	10F8.3	2	DA	Basin area	km^2	.1-5000	•
			P2	Rainfall correction factor		0.5-1.5	•
			TP5	TP-40 10-yr frequency 0.5 h rainfall	mm	5.0-150	Table I.1
			TP6	TP-40 10-yr frequency 6.0 h rainfall	mm	25-200	•
			TP24	Number years record max 0.5 h rain		5-100	•
			BA	Sediment routing coefficient--aggregation		0-1.0	User specified
			BD	Sediment routing coefficient--degradation		0-1.0	•
			YLT	Latitude of watershed	deg	-90-90	•
			BRT	Basin lag time	days	0-120	•
			FFC	Fraction of field capacity--initial water storage		0-1	•
4. Sub-basin centroid coordinates	10F8.3	1	XIJ	X-centroid coordinates of sub-basins	km	0-200	•
			YIJ	Y-coordinates of sub-basins	km	0-200	•
5. Temperature data	12F6.3	3-11	OBMX	Average monthly maximum air temperature	°C	-10-42	•
			OBMN	Average monthly minimum air temperature	°C	-30-30	•
			VOBMX	If HSIH=3, average monthly maximum air temperature	°C	-10-42	•
			VOBMN	If HSIH=3, average monthly minimum air temperature	°C	-30-30	•
			CVT	Coefficient of variation for monthly temperature		0-1	•
6. Solar radiation data	12F6.3	1	OBSL	Monthly average daily solar radiation	ly	20-750	•
7. Monthly rainfall data	12F6.3	1	WI	Monthly maximum 0.5 h rainfall	mm	0-125	Table I.1
8. Precipitation parameters	10F8.3	12	PRW(1)	Monthly probability of wet day after a dry day	---	.001-.95	•
			PRW(2)	Monthly probability of a wet day after a wet day	---	.01-.95	•
			RST(1)	Monthly mean of daily precipitation	mm	0-500	•
			RST(2)	Monthly standard deviation of daily precipitation	mm	.05-200	•
			RST(3)	Monthly skew coefficient of daily precipitation	---	1-7	•
9. Basin data	10F8.3	1	FLU	Fraction of basin in each sub-area		0-1	User specified
	10F8.3	1	CN2	SCS runoff curve number--condition II		5-95	Table II.1
	10F8.3	1	SALB	Soil albedo		.05-.20	Appendix IV
	10F8.3	1	SNO	Initial water content of snow	mm	0-150	User specified
	10F8.3	1	TT	Travel time from sub-basin outlets to basin outlet	hrs	0-50	•
	10F8.3	1	CHL	Channel length from most distant point to sub-basin outlet	km	.05-200	Appendix V
	10F8.3	1	CHS	Average channel slope	m/m	.0001-10	•
	10F8.3	1	CHK	Effective hydraulic conductivity in channel alluvium	mm	0-150	Table II.3
	10F8.3	1	CHN	Channel N value		.01-.3	Table II.2
	10F8.3	1	OVN	Overland flow N value		.01-.3	•
	10F8.3	1	RT	Return flow travel time	days	0-180	User specified
	10F8.3	1	CSS	Sediment concentration in return flow	ppm	100-1500	•
	10F8.3	1	EK	USLE soils factor K		.05-.60	Appendix I
	10F8.3	1	ECP	USLE erosion control practice factor P		.1-1.0	Table III.1
	10F8.3	1	SL	Average slope length for each sub-basin	m	10-150	Appendix V
	10F8.3	1	STP	Average slope steepness for each sub-basin	m/m	.0001-.60	•
10. Routing data (sub-basin to basin outlet)	10F8.3	1	CHW	Average channel width	m	1-1000	•
	10F8.3	1	CHD	Average channel depth	m	.5-30	•
	10F8.3	1	CHSS	Channel slope	m/m	.0001-10	•
	10F8.3	1	CHLL	Channel length	km	.05-200	•
	10F8.3	1	CHNN	Channel N value		.01-.3	Table II.2
	10F8.3	1	CHKK	Effective hydraulic conductivity in channel alluvium	mm/hr	0-150	Table II.3

11. Stockpond data	10F8.3	1	FP	Fraction of each sub-basin that flows into ponds		0-1	User suppl
	10F8.3	1	SAX	Total surface area of all ponds in each sub-basin	ha	0-1000	•
			VHX	Runoff volume from pond catchment area required to fill empty ponds	mm	0-100	•
	10F8.3	1	VH	Initial pond volumes	mm	0-100	•
			CS	Initial sediment concentration	ppm	0-5000	•
	10F8.3	1	CFP	Normal sediment concentration	ppm	0-5000	•
	10F8.3	1	HC	Hydraulic conductivity of pond bottoms	mm/hr	0-1	•
12. Reservoir data	10F8.3	1	FR	Fraction of each sub-basin that flows into reservoirs		0-1	•
	10F8.3	1	SAF	Total reservoir surface area at emergency spillway	ha	0-3000	•
	10F8.3	1	VRF	Runoff volume from reservoir catchment area required to fill emergency spillway	mm	0-300	•
	10F8.3	1	SAS	Total reservoir surface area at principle spillway	ha	0-1000	•
	10F8.3	1	VRS	Runoff required to fill to principle spillway	mm	0-100	•
	10F8.3	1	VR	Initial reservoir volumes	mm	0-100	•
	10F8.3	1	RRR	Average principle spillway release rate	$m^3/s/km^2$	0-1	•
	10F8.3	1	CSR	Initial sediment concentration in reservoirs	ppm	0-5000	•
	10F8.3	1	CFR	Normal sediment concentration in reservoirs	ppm	0-5000	•
	10F8.3	1	HCR	Hydraulic conductivity of reservoir bottoms	mm/h	0-1	•
13. Soil data	10F8.3	1	Z	Depth to bottom of layers	mm	10-3500	Appendix I:
	10F8.3	1	T1	Bulk density	t/m^3	.05-2.6	•
	10F8.3	1	T4	Available water capacity	m/m ?	0-1.0	•
	10F8.3	1	SC	Saturated conductivity	mm/h	0.200	•
	10F8.3	1	CLA	Clay content	%	0-100	•
	10F8.3	1	SIL	Pass #200 sieve	%	0-100	
14. Crop data	2014	1	MO	Month of planting	mos	1-12	User specif
			IDA	Day of month of planting	days	1-31	•
			MOH	Month of harvest	mos	1-12	•
			IDH	Day of month of harvest	days	1-31	•
			ITIL	Code for tillage operation--1=fall plow, 2=spring plot, 3=conservation tillage, 4=zero tillage		1-4	•
			IRO	Vegetation--1-annual (crops), 2=perennial (forest, range, meadow, etc.)		1-2	•
	10F8.3	1	CVM	Average annual C factor for sub-basin		.001-.5	Table VI.1
			BLAI	Maximum LAI for sub-basin		.5-7	•
ily rainfall and mperature data	(5X, 15F5.1)	1		Daily precipitation for each sub-basin	mm	0-250	User suppli
				Daily maximum and minimum temperature for each sub-basin	°C	-50-54	•

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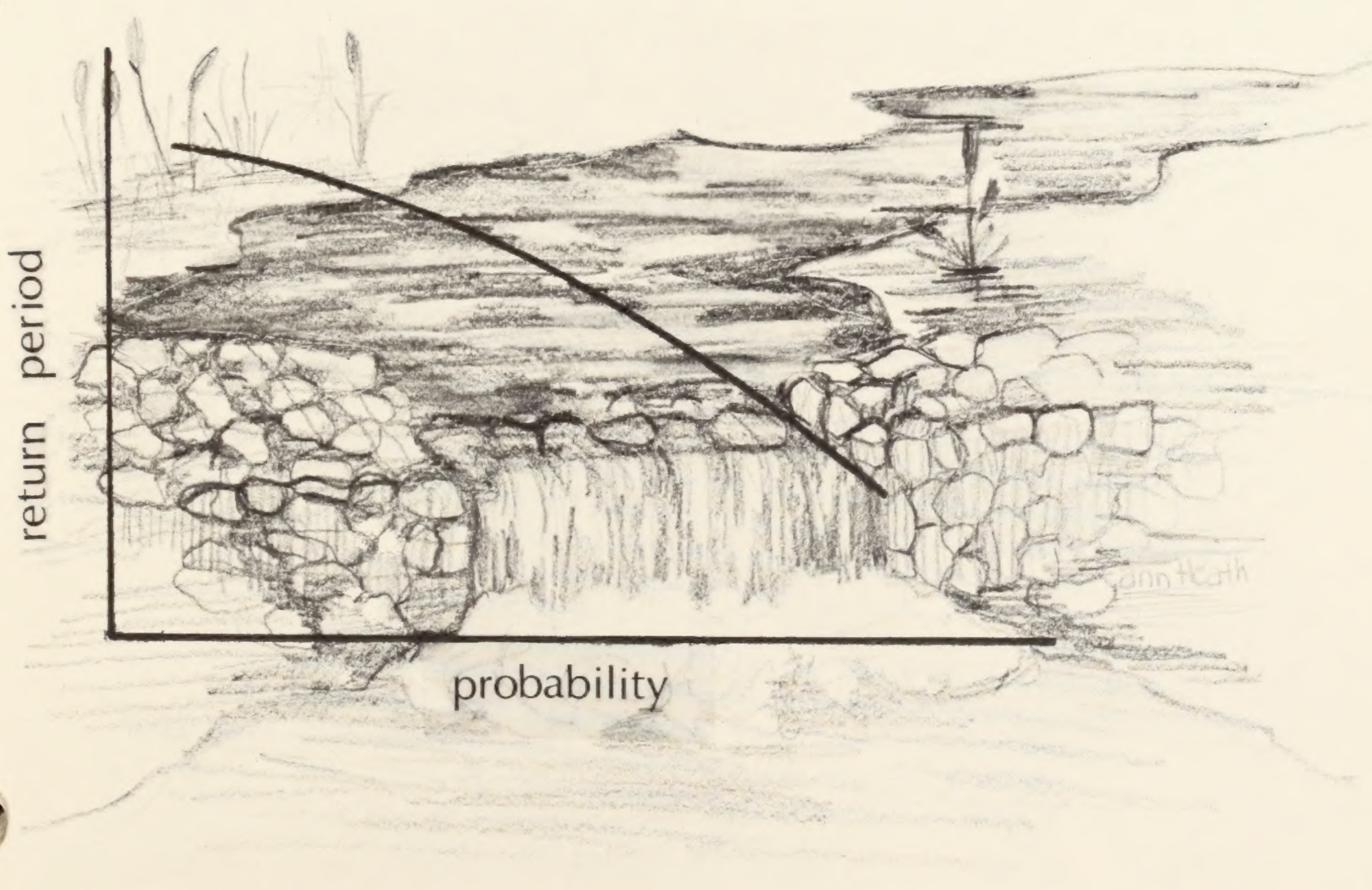
TECHNICAL NOTE

U.S. DEPARTMENT OF THE INTERIOR – BUREAU OF LAND MANAGEMENT

Hydrologic Risk and Return Period Selection for Water Related Projects

by
Bruce P. Van Haveren



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FOREWORD

This Technical Note provides guidance to the hydrologist (and other specialists involved with water projects) who is or may be faced with the task of determining a design hydrologic event for a project that involves a hydrologic risk, such as bridges, culverts, land treatments, fish habitat improvements, watershed management projects, etc. Included is a discussion of hydrologic risk that defines both the manager's and hydrologist's roles in determining risk levels for BLM-funded projects. An extensive section on frequency of hydrologic events is included for the hydrologist, followed by a section on guidelines and graphical aids for determining return periods. The latter section includes problem-oriented examples of return period selection.

Flood frequency analysis is only briefly discussed. This subject will be covered in detail in a forthcoming BLM Technical Note.

INTRODUCTION

Hydrologists are frequently asked to provide design flows or stages for spillways, bridge openings, culverts, diversion dams, waterways, fish improvement structures, watershed improvement projects, and land treatment measures. Too often a return period or recurrence interval is arbitrarily chosen or a standard return period is used by the hydrologist.

The design event chosen by the hydrologist should be based on the risk of failure rather than on an arbitrary or predetermined return period, incorporating the fact that risk increases with increasing project life.

Since failure of a structure exposes the Federal government to potential liability claims, the acceptance of a certain level of risk of failure represents an important management decision.

The purpose of this Technical Note is to assist the hydrologist in understanding hydrologic risk and in communicating this understanding to the land manager. Secondly, with the statistical relationships and tables and graphs included in it, this Technical Note should serve as a reference for the hydrologist and other specialists involved with water-related projects where the frequency of hydrologic events is a concern.

ACCEPTANCE OF HYDROLOGIC RISK AS A MANAGEMENT RESPONSIBILITY

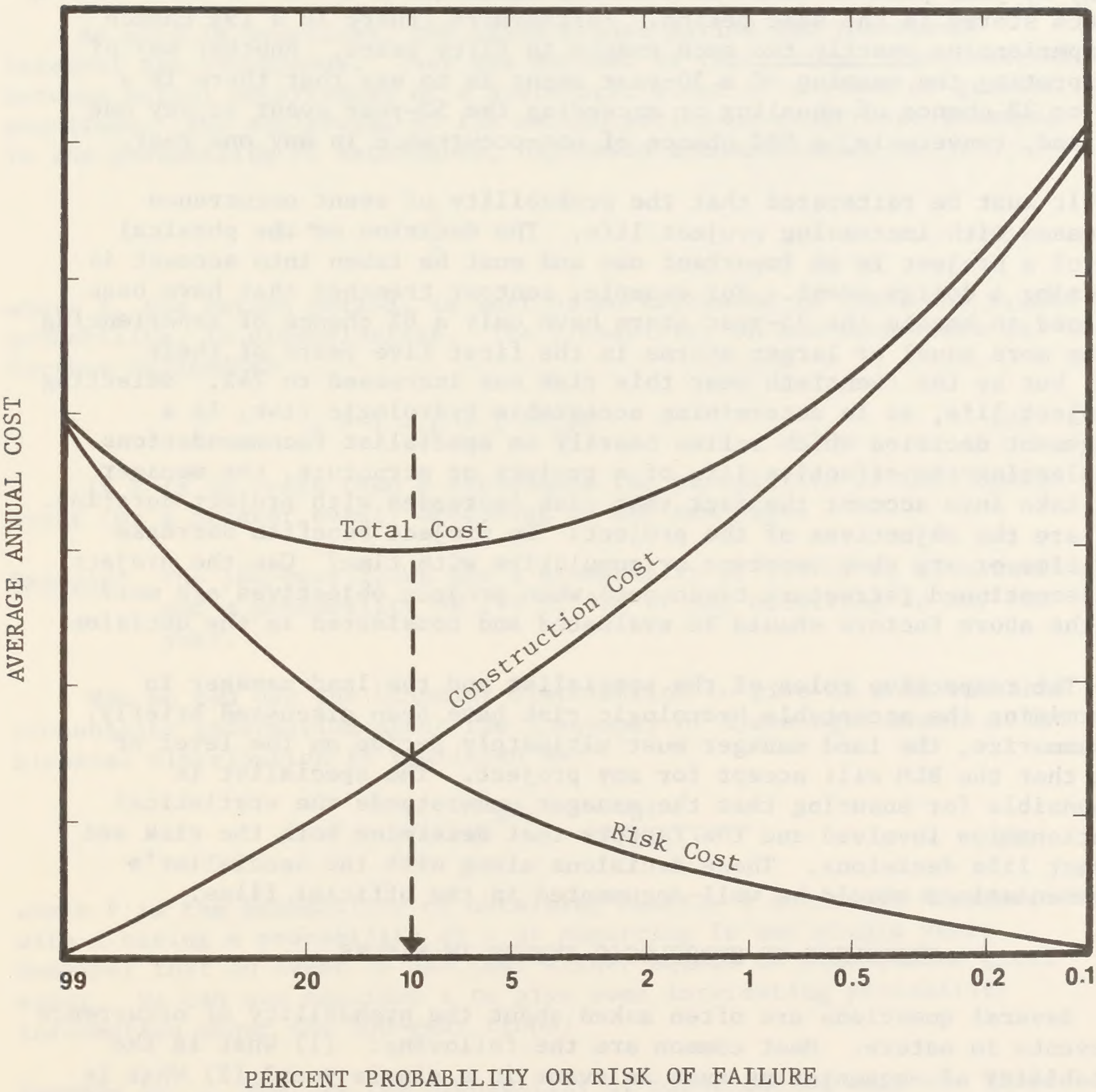
In water-related projects or structures, risk is equivalent to the probability of failure of the structure. The total risk of failure is made up of both hydrologic risk and structural risk. Structural risk refers to the probability that a structure will fail during an event of lower magnitude than the design event. Hydrologic risk is composed of the true or basic risk, which is due to the vagaries of nature, and uncertainty, which is a function of measurement inconsistencies, loss of information during analysis, or non-homogeneity of the data in time.

If we assume that structural risk is zero or near zero for hydrologic events not exceeding the design event, and that hydrologic uncertainty can be handled with confidence limits in the frequency analysis, then the remaining unknown variable is basic hydrologic risk. For large projects, the manager may want to conduct an elaborate study of the economically and politically optimum design for the project. This can be done as shown in Figure 1. The construction costs include the total cost of building the structure averaged over the expected project life plus annual maintenance costs. The risk costs include all those costs that would be incurred should the project or structure fail. For projects that impound water, these costs should include project replacement costs, downstream damage costs, liabilities from deaths and injuries, environmental damages, and the associated inconveniences and political consequences of project failure. The optimum design, from Figure 1, is where the construction cost balances the risk cost.

For small projects, the manager must still weigh the cost of constructing the project against the risk cost and attempt to minimize both. For example, constructing a stream stabilization structure to withstand a 50-year flood event is more expensive than designing it for a 10-year flood event. However, the environmental consequences of the structure failing at the 10-year design level (approximately five times more frequently) may dictate designing for the 50-year flood. On the other hand, where the costs of failure are negligible, as in a secondary road culvert, the manager can easily accept a much higher risk, on the order of 10 to 20%. Acceptance of a given hydrologic risk, say 5%, means the manager is 95% confident that the associated hydrologic event will not be equalled or exceeded in the stated time period, and that the structure or project will not fail for hydrologic reasons.

FIGURE 1

AVERAGE ANNUAL COSTS FOR DIFFERENT PROJECT DESIGNS
(Example only)



Many laymen and occasionally some hydrologists become confused about the real meaning of storm or flood return periods. For example, the commonly referred to 50-year storm does not mean that there will be one and only one such storm every 50 years. In fact, there is only a 37% chance that the 50-year storm will be equalled or exceeded only once in any 50-year period. There is a nearly equal (36%) chance of experiencing no such storms in the same period. Furthermore, there is a 19% chance of experiencing exactly two such events in fifty years. Another way of interpreting the meaning of a 50-year event is to say that there is a 1/50 or 2% chance of equaling or exceeding the 50-year event in any one year and, conversely, a 98% chance of non-occurrence in any one year.

It must be reiterated that the probability of event occurrence increases with increasing project life. The decision on the physical life of a project is an important one and must be taken into account in selecting a design event. For example, contour trenches that have been designed to handle the 75-year storm have only a 6% chance of experiencing one or more equal or larger storms in the first five years of their life, but by the twentieth year this risk has increased to 24%. Selecting a project life, as in determining acceptable hydrologic risk, is a management decision which relies heavily on specialist recommendations. In selecting the effective life of a project or structure, the manager must take into account the fact that risk increases with project duration. What are the objectives of the project? Do project benefits decrease over time or are they constant or cumulative with time? Can the project be discontinued (structure taken out) when project objectives are met? All the above factors should be evaluated and considered in the decision.

The respective roles of the specialist and the land manager in determining the acceptable hydrologic risk have been discussed briefly. To summarize, the land manager must ultimately decide on the level of risk that the BLM will accept for any project. The specialist is responsible for ensuring that the manager understands the statistical relationships involved and the factors that determine both the risk and project life decisions. These decisions along with the specialist's recommendations should be well-documented in the official files.

FREQUENCY OF HYDROLOGIC EVENTS IN NATURE

Several questions are often asked about the probability of occurrence of events in nature. Most common are the following: (1) What is the probability of encountering such an event in a single year? (2) What is the probability of encountering the event in a period of years? and (3) What is the probability of encountering more than one such event in a period of years? All these questions can be answered with the help of the binomial distribution,

$$f(x) = \frac{N!}{x!\ (N-x)!} \quad p^x(1-p)^{N-x} \tag{1}$$

which is found in any standard statistical or mathematical probability text. The binomial distribution has tremendous value in hydrologic studies.

As used in hydrology, the terms return period and recurrence interval are synonymous. They are defined as the average time interval between actual occurrences of a hydrologic event of a given or greater magnitude. The reciprocal of the return period or recurrence interval is the probability of exceedance, expressed mathematically as

$$p = \frac{1}{T} \tag{2}$$

where T, the return period, is most often expressed in years and p, the probability, is dimensionless. The probability of non-occurrence (q) is further defined as

$$q = 1 - p = 1 - 1/T \tag{3}$$

If T is in years then p represents the probability of the T-year event (or a greater event) occurring in any one year.

<u>Example</u>: The 100-year flood has a probability of .01 or 1% of occurring and a probability of .99 or 99% of <u>not</u> occurring in any one year.

Now we can use the binomial distribution to give us some valuable probability information about the frequency of hydrologic events. The binomial distribution is rewritten as:

$$P = p^i(1-p)^{N-i} \quad \frac{N!}{i(N-i)!} \tag{4}$$

where P is the probability of obtaining exactly i events in N years, with i having a probability of p of occurring in any single year. Remember that an event is one that either equals or exceeds the given event. We can use equation 4 to give some interesting probability information about the 100-year flood:

<u>Example 1:</u> What is the probability of experiencing only one flood in 100 years that equals or exceeds the 100-year flood?

Answer: The probability of one and only one event equal to the 100-year flood occurring in 100 years is 37% or 37 chances out of a 100.

Example 2: What is the probability of experiencing no floods equal to or greater than the 100-year flood in a 100-year period?

Answer: Equation 4 reduces to

$$P = (1-p)^N \text{ or } q^N \qquad (5)$$

The probability of no 100-year events occurring in 100 years is 37%.

We can use the complement of equation 5 to find out the probability of experiencing one or more events equal to or greater than the 100-year event in a 100-year period, or

$$P = 1 - q^N \qquad (6)$$

From Example 2, $P = 1 - .37$ or $p = 63\%$

Equation 6 was used to construct the following table of probabilities:

Table 1. Percent Probability of Occurrence of One or More Events Equal to or greater than the T-year event in N years.

No. of Years (N)	Return Period (T), Years											
	5	10	20	25	50	75	100	200	500	1000	5000	10,000
5	67	41	23	18	10	6	5	2	1	*	*	*
10	89	65	40	34	18	13	10	5	2	1	*	*
20	99	88	64	56	33	24	18	10	4	2	*	*
25	**	93	72	64	40	29	22	12	5	3	*	*
50	**	**	92	87	64	49	39	22	10	5	1	*
75	**	**	98	95	78	63	53	31	14	7	1	1
100	**	**	99	98	87	74	63	39	18	10	2	1
200	**	**	**	**	98	93	87	63	33	18	4	2
500	**	**	**	**	**	**	99	92	63	39	10	5
1000	**	**	**	**	**	**	**	99	86	63	18	10
5000	**	**	**	**	**	**	**	**	**	99	63	39
10,000	**	**	**	**	**	**	**	**	**	**	86	63

** greater than 99.5% * less than 1%

Occasionally the hydrologist may want to know the probability of experiencing multiple numbers of events equal to or greater than the return period event.

Equation 4 was used to construct the following table of probabilities related to the 100-year flood:

Table 2: Percent Probability of Occurrence of the 100-year flood.

No. of Years (N)	Number of Events (i)				
	0	1	2	3	1 or more
100	37	37	18	12	63
50	61	31	8	2	39
25	78	20	2	*	22
10	90	9	*	*	10
5	95	5	*	*	5
1	99	1	*	*	1

* less than 1%

Tables 1 and 2 can be used for any set of hydrologic data developed from discrete hydrologic variables, such as streamflow stage or discharge, lake levels, groundwater levels, precipitation, evaporation, etc.

SELECTING THE RETURN PERIOD OF A HYDROLOGIC EVENT

Given the risk level and the project life, the hydrologist can compute the return period from Equation 4 by solving for P. Since this is an unwieldy computation, three graphs have been prepared to make this determination simple. Figure 2 is used to determine the return period corresponding to the risk of experiencing at least one event equal to or greater than the return period event in N years. Figure 3 should be used where the interest is in two or more events equal to or greater than the return period event. Figure 4 is used where the interest is in three or more events equal to or greater than the return period event. Examples of the use of these graphs are shown below:

Figure 2. Return periods corresponding to the probability of experiencing one or more events equal to or greater than the T-year event in N years.

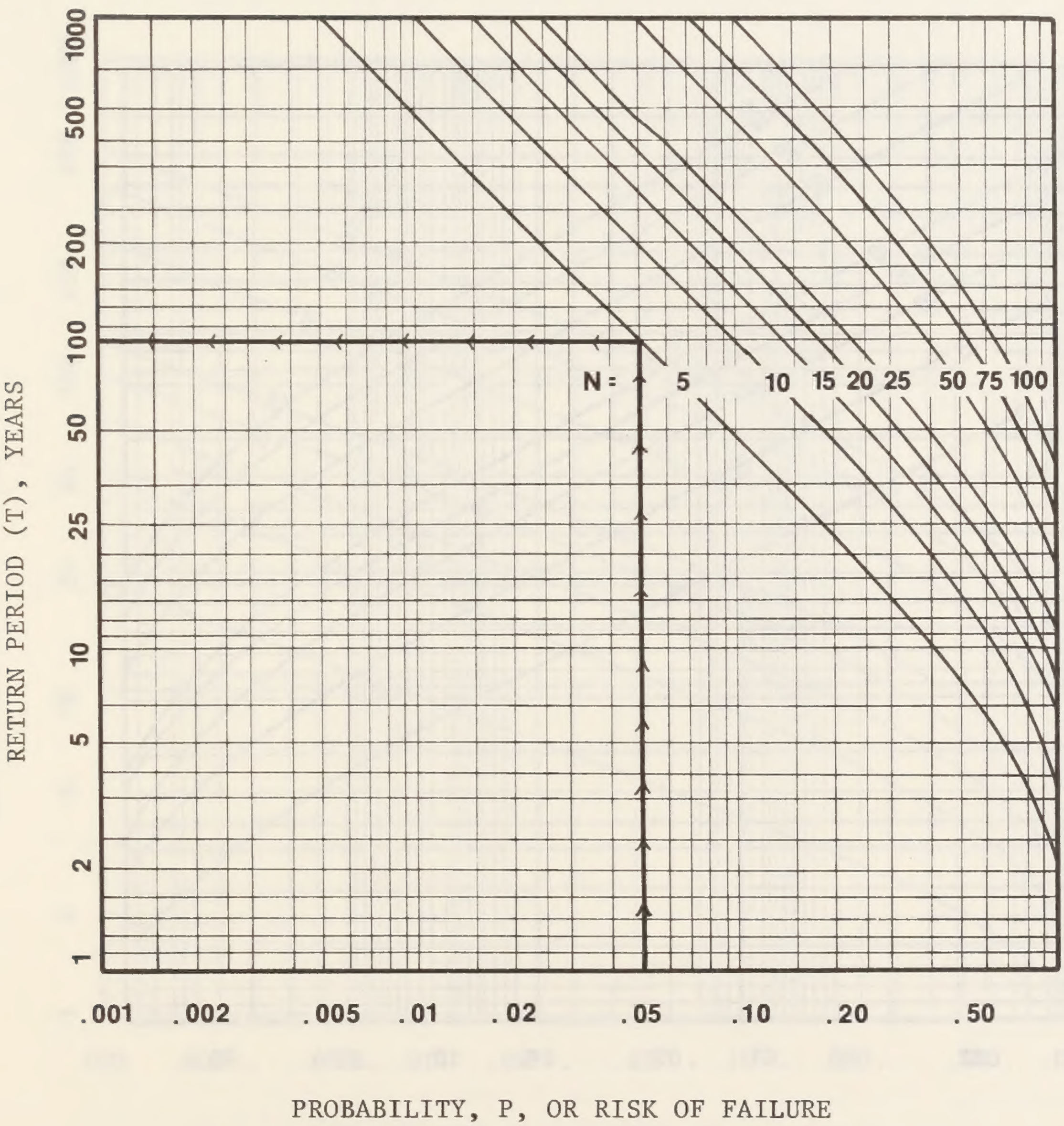


Figure 3. Return periods corresponding to the probability of experiencing two or more events equal to or greater than the T-year event in N years.

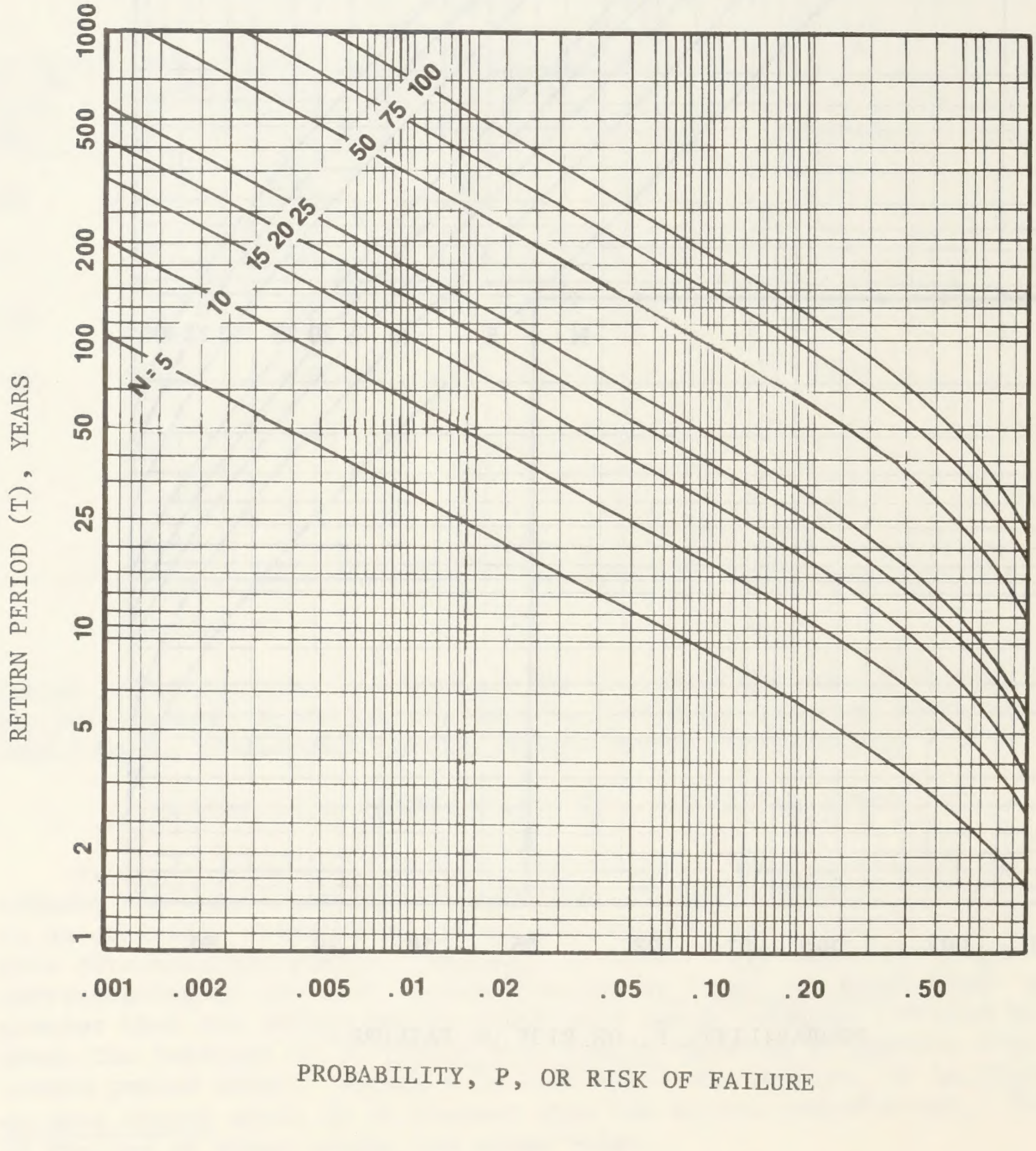
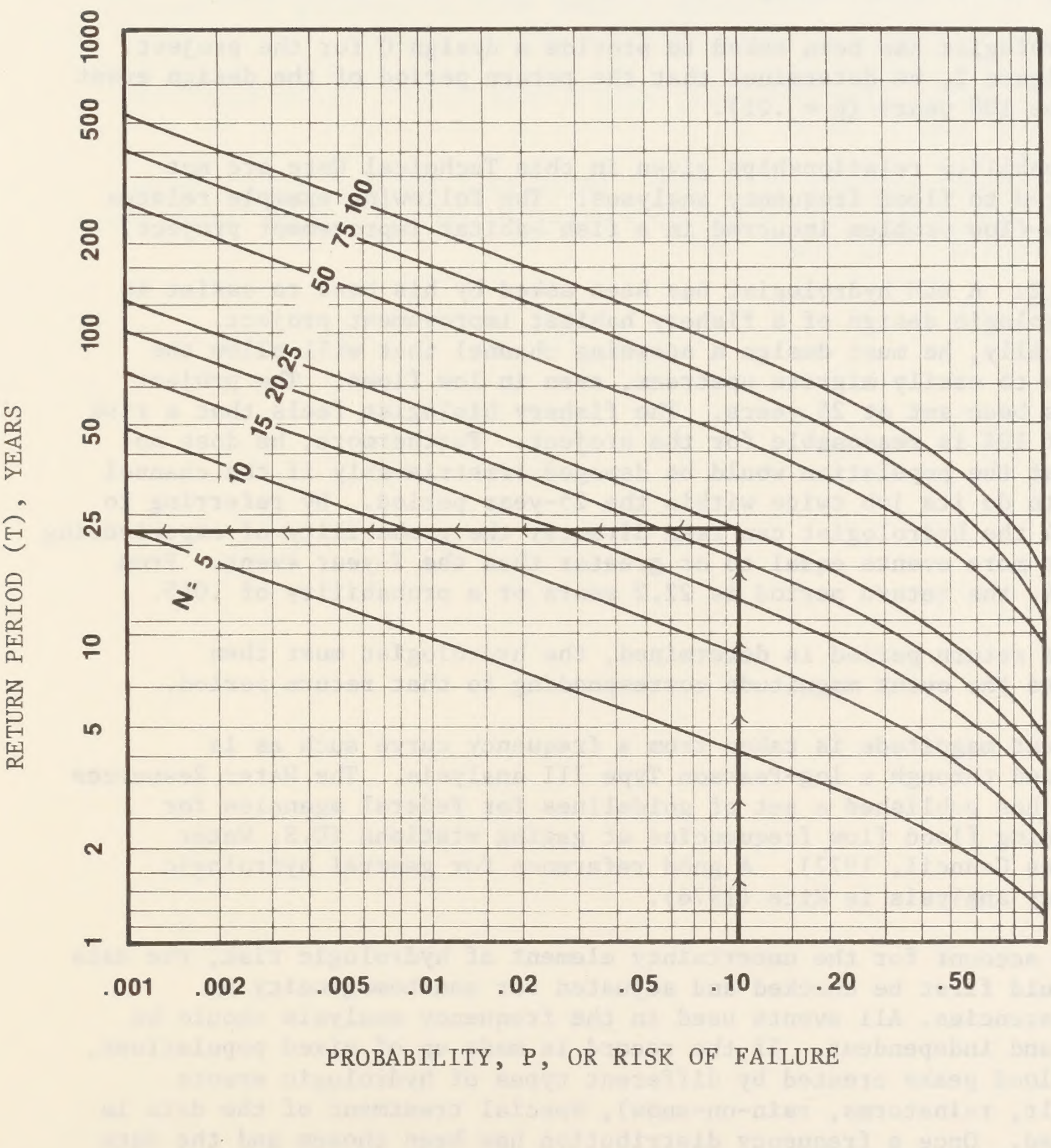


Figure 4. Return periods corresponding to the probability of experiencing three or more events equal to or greater than the T-year event in N years.



Problem 1: A BLM district engineer has been asked to design and build a bridge suitable for use by logging trucks. The bridge will be designed to have a physical and economic life of five years, which is the duration of the associated timber sale contract. Failure of the bridge would not mean a great economic loss, but the associated channel damage and sediment problems created by a bridge failure would impact a critical downstream trout habitat. Because of the environmental hazards, the District Manager has decided on a risk level of 5%.

The hydrologist has been asked to provide a design Q for the project. Using Figure 2, he determines that the return period of the design event should be 100 years ($p = .01$).

The probability relationships given in this Technical Note are not restricted to flood frequency analyses. The following example relates to a low-flow problem incurred in a fish habitat improvement project.

Problem 2: A BLM hydrologist has been asked by his boss to assist in the hydrologic design of a fishery habitat improvement project. Specifically, he must design a spawning channel that will allow the spawners to easily migrate upstream, even in low flows. The project life has been set at 25 years. The fishery biologist feels that a risk level of 10% is reasonable for the project. Furthermore, he does not feel that the population would be damaged irretrievably if the channel failed to do its job twice within the 25-year period. By referring to Figure 4 the hydrologist can read directly the probability of experiencing three or more events equal to or greater than the T-year event. From Figure 4, the return period is 22.2 years or a probability of .045.

Once the return period is determined, the hydrologist must then calculate the event magnitude corresponding to that return period.

This event magnitude is taken from a frequency curve such as is determined through a log-Pearson Type III analysis. The Water Resources Council has published a set of guidelines for Federal agencies for determining flood flow frequencies at gaging stations (U.S. Water Resources Council, 1977). A good reference for general hydrologic frequency analysis is Kite (1976).

To account for the uncertainty element of hydrologic risk, the data set should first be checked and adjusted for non-homogeneity or inconsistencies. All events used in the frequency analysis should be random and independent. If the record is made up of mixed populations, e.g., flood peaks created by different types of hydrologic events (snowmelt, rainstorms, rain-on-snow), special treatment of the data is indicated. Once a frequency distribution has been chosen and the data

fitted to this distribution, confidence limits should be computed for the frequency curve, as explained in U.S. Water Resources Council (1977). The confidence level should be set by the hydrologist in accordance with the way he or she feels about the original data set. A confidence level of 95% is commonly used for most applications but is not a hard-and-fast rule. The upper confidence limit value then becomes the recommended design event for the project.

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HYDROLOGIC DESIGN AND ANALYSIS PROGRAMS FOR THE HONEYWELL SERIES 60 (LEVEL66) /6000 COMPUTER

U.S. DEPARTMENT OF INTERIOR
BUREAU OF LAND MANAGEMENT

HYDROLOGIC DESIGN AND ANALYSIS PROGRAMS WRITTEN IN BASIC

FOR THE

HONEYWELL SERIES 60(LEVEL 66)/6000 COMPUTER

Submitted To

U.S. Bureau of Land Management
Division of Resource Systems
Denver Service Center
Denver Federal Center, Building 50
Denver, Colorado 80225

By

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Denver, Colorado

August 1984

FOREWORD

This volume provides user guidance in the operation of seven hydrologic design and analysis computer programs which have been written for the Bureau of Land Management's (BLM) Honeywell Series 60 (Level 66)/6000 computer. Program background and computational procedures are described, including program uses and limitations. A worked example problem in the form of a sample run is provided. The programs are written in BASIC. They are designed to be completely interactive and easy to use.

The objective in having these programs written is to make commonly used but computationally cumbersome analytical procedures readily available to field office specialists working on problems of hydrologic design and analysis. The computational procedures were originally developed for handheld programmable calculators. Programs 1-4 were derived in part from calculator programs prepared for the USDI Office of Surface Mining, Region V (Report H-D3004/030-81-1029F). "Small Calculator Programs for Analysis of Waterbeds and River Systems", by the Colorado State University Research Institute, served as a reference for Programs 5 and 6. Program 7 was derived in part from a program developed for Hewlett-Packard 67 calculator by L. Busack, Monaco, PA.

This user guide is prepared in loose-leaf format to provide the user maximum flexibility in maintaining and expanding a useful library of hydrology programs.

Any questions should be directed to the Division of Resource Systems, D-471, (303) 236-0170, FTS 776-0170.

Denver Service Center
September 1984

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PROGRAM SUMMARIES

PROGRAM: FLOOD (Flood Routing, Dam Breach Analysis)
ACCESS: *BRN A403/FLOOD, R
DESCRIPTION: This program routes a set of inflow hydrographs through a multiple channel and/or reservoir system using the Muskingam and Puls methods. The program also provides the option of analyzing expected flows due to a dam breach by either overtopping or piping. Up to 100 channel and/or reservoir segments can be routed, up to 10 of which can be reservoirs. Each reservoir can have up to 10 arbitrary increasing stage/discharge/storage values. Up to five segments can be confluent into a single segment. Inflow hydrographs to headwater segments can be input from the keyboard or from a previously saved data file. Inflow hydrographs must define flows for each time step.

The dam breach analysis requires that water levels and dimensions of the breach be specified as per a diagram which appears on the screen. The dam breach option can also be used to generate stage/discharge/storage values for input to the routing routine.

PROGRAM: BACKH2O (Backwater Curve)
ACCESS: *BRN A403/BACKH2O, R
DESCRIPTION: This program uses the direct step method to determine a water surface profile and flow velocities under gradually varied flow conditions for a fixed rate of flow in a trapezoidal, rectangular, or triangular channel by the standard step method.

The program also provides the capability to determine normal flow depth or critical flow depth for a given channel cross section, Manning's n, and flowrate. These depths can then be used as starting or ending points for determining downstream or upstream water surface profiles and flow velocities. This program will also generate a water surface profile plot when requested by the user.

PROGRAM: PEARSON (Log Pearson Type III Flood Analysis)
ACCESS: *BRN A403/PEARSON, R
DESCRIPTION: This program fits a series of flow events such as peak annual flows to a Log Pearson Type III distribution. This distribution is commonly used to predict flood recurrence intervals. Initial data input for a given gaging station is the number of

measured peak flows and the amount of each flow in cubic feet per second (CFS). If flow data for a particular gaging station has been previously analyzed, and the resulting output saved to a disk file, the disk file may be called up at the user's request in order to avoid re-inputting all of the flow amounts. Previously entered flows may also be edited and added to during later program runs. The program is limited to 200 flows per gaging station. The program begins by asking for the name of the file the output is to be written to. If an output file has been previously generated, the same file name may be used, or a different file name may be used to separate the results.

PROGRAM: USLE (Universal Soil Loss Equation)
ACCESS: *BRN A403/USLE, R
DESCRIPTION: The program uses the Universal Soil Loss Equation (USLE) to estimate soil loss from a given acreage of land. The USLE is an empirically developed formula intended to estimate soil loss on agricultural lands. The USLE only accounts for sheet and rill erosion. No erosion from gullying is considered. In the western U.S., gully erosion is often the principal source of sediment. Thus, the USLE may not represent a comprehensive total of erosion from an area in the western U.S. The USLE only considers average erosion, not the sediment delivery ratio to a stream channel. When applying the USLE to estimate sediment impacts on surface water quality, the total erosion computed by the USLE must be adjusted with the appropriate sediment delivery ratio. This program allows the option of a sediment delivery ratio to be input after the amount of average soil erosion has been calculated.

PROGRAM: GREEN (Green and Ampt Infiltration Analysis)
ACCESS: *BRN A403/GREEN, R
DESCRIPTION: This program uses the Green - Ampt infiltration equation to compute incremental and cumulative excess rainfall and infiltration volume. The program implements the homogeneous soil version for time varying rainfall as represented by a hyetograph. Required input includes the average suction head and the conductivity in the wetted zone. The rainfall intensity hyetograph may be input from the keyboard or from a previously generated data file.

PROGRAM: MPM (Meyer-Peter, Muller Bedload Transport Equation)
ACCESS: *BRN A403/MPM, R
DESCRIPTION: This program uses the Meyer-Peter, Muller equation to compute the bedload transport rate for a given sediment size range. The program also computes the suspended sediment transport rate using a numerical integration of an approach developed by Einstein. Program output includes bedload and suspended load for each size range input as well as the total transport rate for all size ranges input (for a given rate of flow). Required input includes the Darcy-Weisbach friction factor, kinematic viscosity, the flow velocity, the width of flow, channel slope, and depth of flow.

PROGRAM: POND (Detention Pond Design)
ACCESS: *BRN A403/POND, R
DESCRIPTION: This program calculates the pond volume required to detain the excess runoff occuring because of a change in basin runoff conditions. Detention pond volume is calculated using estimated peak inflow, desired peak outflow, and the expected excess runoff volume. Excess runoff volume can either be input directly (pre- and post rainfall excess) or can be calculated using SCS methods (pre- and post Curve Numbers). The program will also calculate expected peak outflow from a detention pond given rainfall excess, storage capacity, and peak inflow.

1. FLOOD ROUTING AND DAM BREACH ANALYSIS

I. Introduction

Streamflow routing is the technique used in hydrology to compute the effect of channel storage on the shape and movement of a flood wave (1). The same principles also apply to computing the effect of reservoir storage on the shape of a flood wave. This program routes a flow through a series of channels and reservoirs using the Muskingum method for the channel segments and the Puls procedure for the reservoir segments. The progam also provides a subroutine which uses standard weir and orifice formulas for the analysis of expected flows due to a dam breach by either overtopping or piping.

II. Program Theory

The Puls and Muskingum methods are the most-employed hydrologic flood routing techniques for reservoirs and channels. Both are traditionally solved in tabular form with graphical aids and both are derived from conservation of flow over discrete time steps (2). The Puls method assumes a constant discharge-storage relationship for the given reservoir being assessed. For a given time interval, the change in storage for a reservoir segment is the difference between inflow and outflow:

$$I - O = \Delta S , \qquad [1\text{-}1]$$

or, if expressed in finite time intervals,

$$1/2(I_1 + I_2)\,\Delta t - 1/2(O_1 + O_2)\,\Delta t = S_2 - S_1 , \qquad [1\text{-}2]$$

where the subscripts indicate the routing periods, and I, O, and S are instantaneous values of inflow, outflow, and storage, respectively, at the beginning of the routing periods indicated (1). The equation can be arranged so that all of the known values are on the left:

$$1/2(I_1 + I_2)\,\Delta t + S_1 - 1/2\,O_1\,\Delta t = S_2 + 1/2\,O_2\,\Delta t. \qquad [1\text{-}3]$$

During routing the known values are substituted into the above equation to obtain $S_2 + 1/2\,O_2\,\Delta t$. O_2 can then be obtained from the relationship between O_2 and $S_2 + 1/2\,O_2\,\Delta t$ using the discharge-storage curve (1).

The Muskingum method was developed in conjunction with the Muskingam Conservancy District Flood-Control Project of the U.S. Army Corps of Engineers in 1934-35 (4). The method utilizes the concept of wedge and prism storage. When steady flow exists, storage volume can be related to outflow by a simple linear function. During the advance of a flood wave steady flow does not exist (i.e., inflow exceeds outflow) and a wedge of storage is produced. During the recession of a flood wave, outflow exceeds

inflow and a negative wedge storage results. In the Muskingam method, the wedge is related to the difference between instantaneous values of inflow and outflow. The method also accounts for the remaining channel storage, termed prism storage. The total storage then becomes:

$$S = KO + KX(I - O). \qquad [1\text{-}4]$$

This is the Muskingam equation where prism storage is represented by the first expression (KO) and wedge storage is represented by the second expression (KX(I-O)). In these expressions K is a coefficient termed the storage time constant, and X is a weighting factor between 0 and 0.5 (typically 0.2 - 0.3).

Using the symbols as defined above for the Puls method, the Muskingam equation can be written as:

$$S_2 - S_1 = K[X(I_2 - I_1) + (1 - X)(O_2 - O_1)]. \qquad [1\text{-}5]$$

Combining this equation with Eq. 1-2 and simplifying,

$$O_2 = C_1'I_2 + C_2'I_1 + C_3'O_1 \qquad [1\text{-}6]$$

where,

$$C_1' = \frac{\Delta t - 2KX}{2K(1 - X) + \Delta t} \qquad [1\text{-}7]$$

$$C_2' = \frac{\Delta t + 2KX}{2K(1 - X) + \Delta t} \qquad [1\text{-}8]$$

and,

$$C_3' = \frac{2K(1 - X) - \Delta t}{2K(1 - X) + \Delta t} \quad (\underline{1}). \qquad [1\text{-}9]$$

K and X are usually estimated through a plotting analysis of known flood hydrographs. Sometimes K is estimated as the travel time through a reach. Discussions of how these parameters may be estimated can be found in *Handbook of Applied Hydrology* (1), and *Hydrology for Engineers* (3). The flood routing program is based in large part on the algorithms supplied in *Flood Routing on a Small Computer* (2). The form in which the program is written requires a minimum amount of memory because overlaying techniques are incorporated to utilize the same array variables repeatedly to store different data. The limitations on the number of time steps and channel and reservoir segments which can treated for a single problem can be increased by adjusting the (DIM)ension statements for these array variables in the program source code if the user so desires. For further information on how the Muskingam and Puls methods are implemented in the program the user should consult the above referenced article.

The weir and orifice equations used for the dam breach subroutine in the program are as follows:

Rectangular Weir

$$Q = 3.075\ L\ D^{1.5} \qquad [1\text{-}10]$$

Triangular Weir

$$Q = 1.156\ L\ D^{1.5} \qquad [1\text{-}11]$$

Parabolic Weir

$$Q = [0.809+3.66(L/2D)^{2}-1.02(L/2D)^{4}+0.124(L/2D)^{6}]D^{2.5} \qquad [1\text{-}12]$$

Rectangular Orifice

$$Q = 4.78\ H\ L\ D^{.5} \qquad [1\text{-}13]$$

Circular Orifice

$$Q = 3.754\ L^{2}\ D^{.5} \qquad [1\text{-}14]$$

where L, H, and D are width, height, and depth respectively of the breach. For a discussion of how the form and coefficients for these equations were derived the user should consult *A Quick Method For Computing Flows From Dam Breaks* (5).

III. Program Operation / Limitations

The flood routing routine is limited to 50 time steps and 100 segments (ten of which may be reservoir segments). For each reservoir, up to ten increasing stage-discharge-storage values may be entered using a reservoir rating curve supplied by the user. The dam breach routine may be utilized to derive the stage-discharge portion of a reservoir rating curve if so desired. For a given problem up to a maximum of five segments can be confluent into a single downstream segment. All headwater segments must be numbered consecutively from one and the other segments must be numbered such that upstream segments have smaller numbers than any segments downstream from them. Reservoir stages and beginning flows in each segment for a given problem are initialized to provide steady-state continuity with initial inflows into the headwater segments. The program then works its way downstream combining inflows at the top of each segment and routing flow to the bottom.

Initial input into the flood routing routine consists of:

1) Total Number of Segments,
2) Number of Headwater Segments,
3) Number of Reservoir Segments,
4) Number of Time Periods, and
5) Length of the Time Steps.

For each channel segment, the user is then prompted for the segment number, the Muskingam weighting value, and the Muskingam storage time constant. The segment numbers, number of rating curve points, and actual rating curve values must then be input for each reservoir segment. Inflow hydrographs into each headwater member can then be entered from the keyboard or from a previously saved data file. Each segment is then routed consecutively starting with segment number one in order of increasing segment number. After each segment is routed, the user is offered the option of generating a plot of the segment outflow hydrograph.

For the dam breach routine, the user must first select the type of breach to be analyzed and then select the weir or orifice shape. A graphic will then appear on the CRT or printer which illustrates the dimensions needed for the selected weir or orifice. For the weir breachs the width and depth of flow are required. For the circular orifice, the depth of flow to the center of the pipe and the diameter of the pipe are required. For the rectangular orifice, the height and width of the pipe and the depth of flow at its center are required. The number of flows which can be evaluated for a given run is unlimited.

IV. Example Problem

Flood Routing

The following example is taken from *Flood Routing on a Small Computer* (5) and consists of the following five segment network:

```
Input Hydrograph -> \            / <- Input Hydrograph
                     o          o
                      \        /
     Segment No. 1 ->  \      /
                        o    / <- Segment No. 2
                         \  /
       Segment No. 3 ->   \ /
                          \/
                          /\
                         /  \ <- Segment No. 4
                        /    \  (Reservoir)
                       /______\
                          |
        Segment No. 5 ->  |
                          o
```

Segments 1 and 2 are headwater segments with associated inflow hydrographs to be input by the user. In this example it is desired that the inflow hydrograph to segment 2 be transfered to the reservoir with no attenuation. In order to achieve this, segment 2 is given a Muskingam weighting factor of 0.5 and a storage time constant of 0.0 (note that the inflow and outflow hydrographs computed for segment 2 in the listing below are identical). The same procedure would be followed in the simple

case requiring the routing of a single inflow hydrograph through a single reservoir segment (i.e., this would be a two segment problem using a single channel segment with a weighting factor of 0.5 and a storage time constant of 0.0 influent into a single reservoir segment).

The reservoir site for this problem has been surveyed and an area-elevation relationship determined as follows:

Elevation (ft)	Area (ft^2)
0.0	0
.3	441,000
.5	435,600
1.0	435,600
1.5	435,600
2.0	435,600
2.5	435,600

The incremental volume of storage for each elevation increment was calculated from:

$$\Delta V = (A_1 + A_2)(z_2 - z_1)/2$$

where A_1 and A_2 are the water surface areas at elevations z_1 and z_2 and ΔV is the volume of storage between elevations z_1 and z_2. As can be inferred from the water surface areas, the reservoir has virtually vertical sides between the elevations .5 and 2.5 feet. The resulting stage-storage values are as follows:

Stage (ft)	Storage (ft^3)
0.0	0
.3	132,300
.5	217,800
1.0	435,600
1.5	653,400
2.0	872,100
2.5	1,089,000

The elevations listed above were then applied to the known geometry and elevation of the weir-shaped outlet structure to derive discharges using an appropriate weir equation which is similar to that used in the dam breach routines in the flood routing program. The resulting stage-discharge-storage values are as follows:

Stage (ft)	Discharge (cfs)	Storage (ft^3)
0.0	0.0	0
.3	1.0	132,300
.5	21.2	217,800
1.0	60.0	435,600
1.5	110.0	653,400
2.0	170.0	872,100
2.5	238.0	1,089,000

The remaining input is self evident in the example run listed below.

*BRN A403/FLOOD, R

This program routes a set of inflow hydrographs through a multiple channel and/or reservoir system using the Muskingam and Puls methods. The program also provides the option of analyzing expected flows due to a dam breach by either overtopping or piping. The following inputs are required for the routing routine:

* Input hydrographs for headwater segments
* Muskingam time constants for channels
* Muskingam weighting values for channels
* Stage/discharge/storage points for reservoirs
* Listing of confluent segments for each segment
* Number of time steps
* Length of each time step

Up to 100 channel and/or reservoir segments can be routed, up to 10 of which can be reservoirs. Each reservoir can have up to 10 arbitrary increasing stage/discharge/storage values. Up to five segments can be confluent into a single segment. Inflow hydrographs to headwater segments can be input from the keyboard or from a previously saved data file. Inflow hydrographs must define flows for each time step.

The dam breach analysis requires that water levels and dimensions of the breach be specified as per a diagram which appears on the screen. The dam breach option can also be used to generate stage/discharge/storage values for input to the routing routine.

```
SELECT THE PROCEDURE DESIRED:

   1 - FLOOD ROUTING
   2 - DAM BREACH ANALYSIS
   3 - END PROGRAM RUN

? 1

TOTAL NUMBER OF SEGMENTS? 5

NUMBER OF HEADWATER SEGMENTS? 2
```

```
NUMBER OF RESERVOIR SEGMENTS? 1

NUMBER OF TIME PERIODS? 15

LENGTH OF TIME STEP (HRS)? .5

ENTER SEGMENT NO., WEIGHTING VALUE, AND TIME CONSTANT FOR EACH CHANNEL:
(Three entries to a line, in above order, separated by commas)

? 1,.21,1.6
? 2,.5,0
? 3,.32,3.1
? 5,.27,1.9

ENTER SEGMENT NUMBER AND NUMBER OF STAGE-DISCHARGE-STORAGE
RATING CURVE POINTS TO BE INPUT FOR RESERVOIR NO.     1 :
(Two entries to a line, in above order, separated by commas)

? 4,7

ENTER STAGE(ft), DISCHARGE(cfs), AND STORAGE(cubic ft) FOR
EACH RATING CURVE POINT FOR RESERVOIR SEGMENT NO.     4 :
(Three entries to a line, in above order, separated by commas)

? 0,0,0
? .3,1,132300
? .5,21.2,217800
? 1,60,435600
? 1.5,110,653400
? 2,170,871200
? 2.5,238,1089000

DO YOU WISH TO ENTER INFLOW HYDROGRAPH FOR SEGMENT NO.     1
FROM THE KEYBOARD OR FROM A PREVIOUSLY GENERATED DATA
FILE ( 1 OR 2 ) ?

     1 - KEYBOARD
     2 - FILE

? 1

ENTER FLOW VALUE FOR EACH OF   15 TIME PERIODS:
(One entry to a line)

? 80
? 90
? 110
? 130
? 120
? 110
? 100
? 90
? 85
? 82
? 80
```

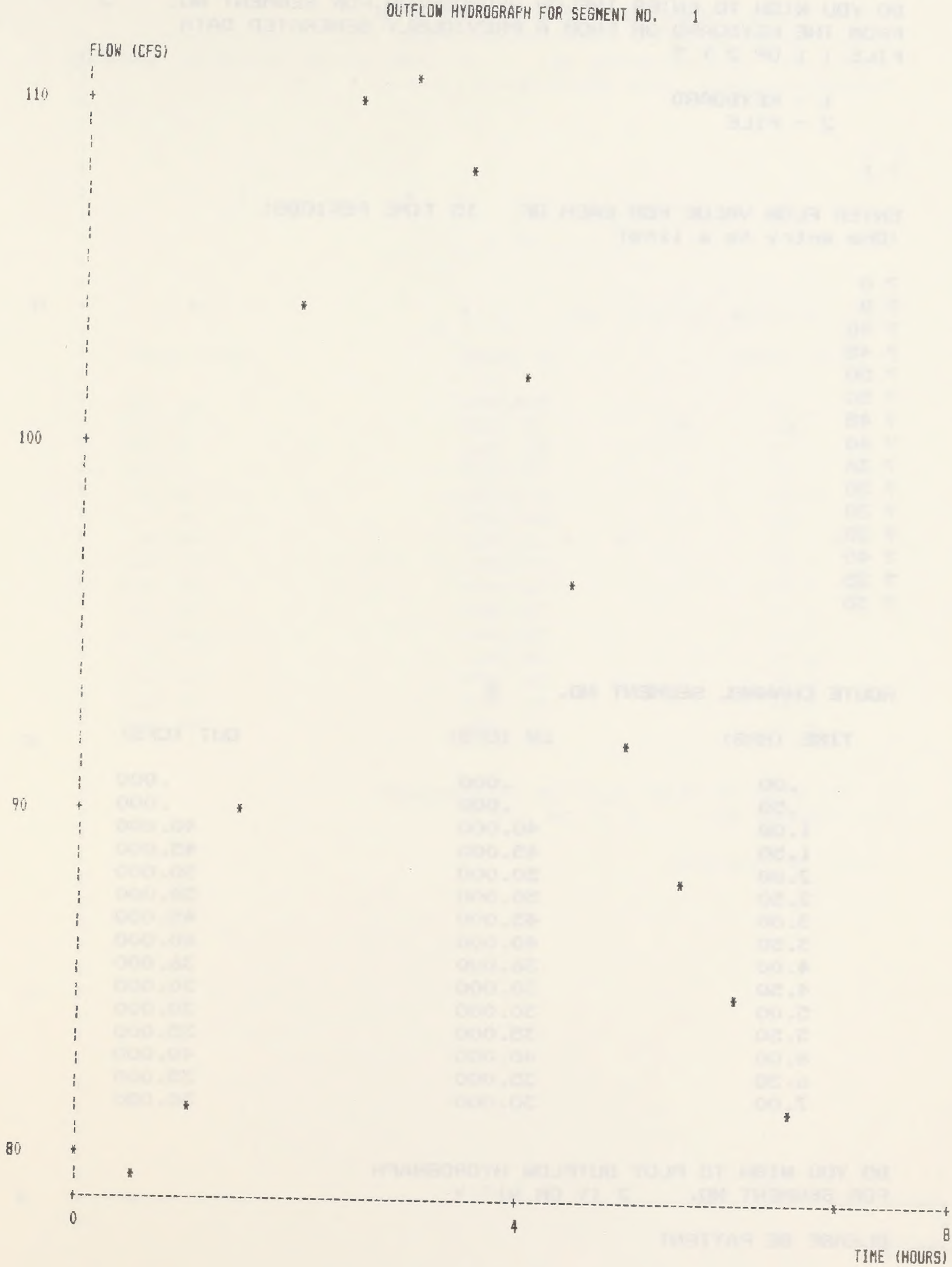
? 78
? 75
? 73
? 70

ROUTE CHANNEL SEGMENT NO. 1

TIME (HRS)	IN (CFS)	OUT (CFS)
.00	80.000	80.000
.50	90.000	79.432
1.00	110.000	81.786
1.50	130.000	89.968
2.00	120.000	103.756
2.50	110.000	109.689
3.00	100.000	110.360
3.50	90.000	107.506
4.00	85.000	102.009
4.50	82.000	96.562
5.00	80.000	91.867
5.50	78.000	88.061
6.00	75.000	84.909
6.50	73.000	81.750
7.00	70.000	79.031

DO YOU WISH TO PLOT OUTFLOW HYDROGRAPH
FOR SEGMENT NO. 1 (Y OR N)? Y

PLEASE BE PATIENT


OUTFLOW HYDROGRAPH FOR SEGMENT NO. 1
FLOW (CFS)
110
100
90
80
0
4
8
TIME (HOURS)

```
DO YOU WISH TO ENTER INFLOW HYDROGRAPH FOR SEGMENT NO.     2
FROM THE KEYBOARD OR FROM A PREVIOUSLY GENERATED DATA
FILE ( 1 OR 2 ) ?

     1 - KEYBOARD
     2 - FILE

? 1

ENTER FLOW VALUE FOR EACH OF   15 TIME PERIODS:
(One entry to a line)

? 0
? 0
? 40
? 45
? 50
? 50
? 45
? 40
? 36
? 30
? 30
? 35
? 40
? 35
? 30


ROUTE CHANNEL SEGMENT NO.     2

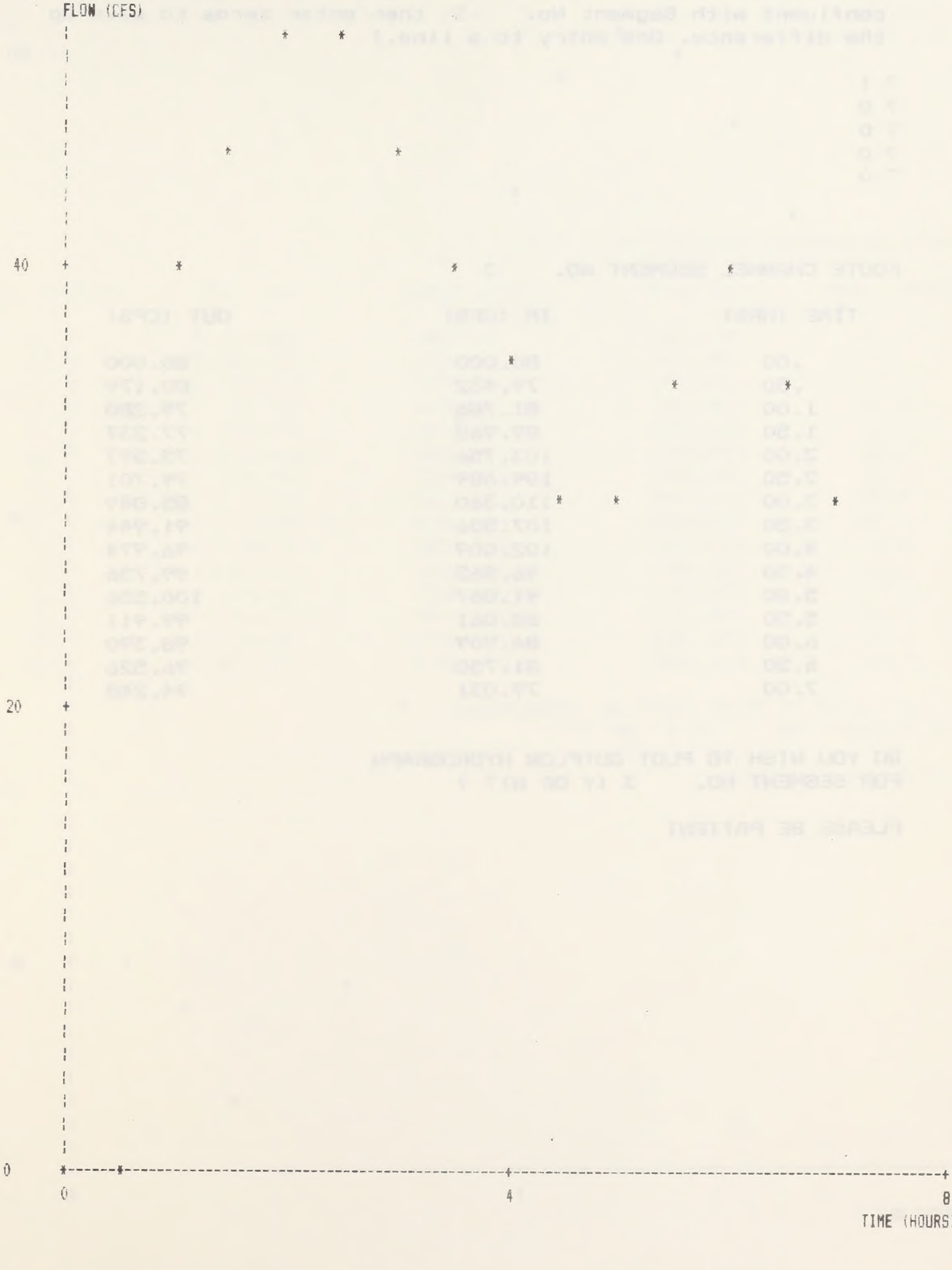
   TIME (HRS)            IN (CFS)               OUT (CFS)

      .00                  .000                   .000
      .50                  .000                   .000
     1.00                40.000                 40.000
     1.50                45.000                 45.000
     2.00                50.000                 50.000
     2.50                50.000                 50.000
     3.00                45.000                 45.000
     3.50                40.000                 40.000
     4.00                36.000                 36.000
     4.50                30.000                 30.000
     5.00                30.000                 30.000
     5.50                35.000                 35.000
     6.00                40.000                 40.000
     6.50                35.000                 35.000
     7.00                30.000                 30.000

DO YOU WISH TO PLOT OUTFLOW HYDROGRAPH
FOR SEGMENT NO.    2 (Y OR N)? Y

PLEASE BE PATIENT
```

OUTFLOW HYDROGRAPH FOR SEGMENT NO. 2



ENTER INFLOW SEGMENTS TO SEGMENT NO. 3 :
(Five values must be entered, if less than five segments are confluent with Segment No. 3 then enter zeros to make up the difference. One entry to a line.)

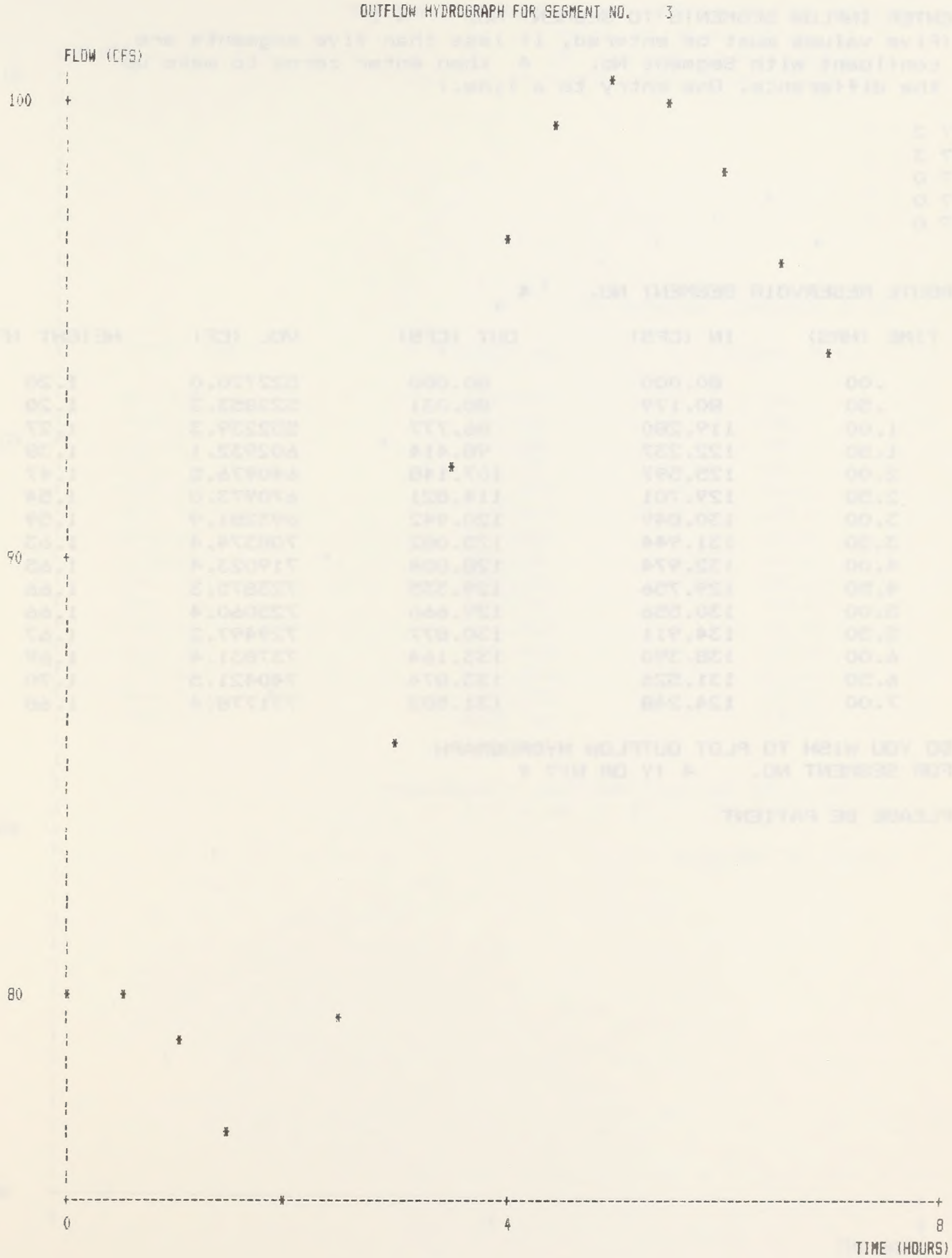
```
? 1
? 0
? 0
? 0
? 0
```

ROUTE CHANNEL SEGMENT NO. 3

TIME (HRS)	IN (CFS)	OUT (CFS)
.00	80.000	80.000
.50	79.432	80.179
1.00	81.786	79.280
1.50	89.968	77.237
2.00	103.756	75.597
2.50	109.689	79.701
3.00	110.360	85.849
3.50	107.506	91.944
4.00	102.009	96.974
4.50	96.562	99.756
5.00	91.867	100.556
5.50	88.061	99.911
6.00	84.909	98.390
6.50	81.750	96.526
7.00	79.031	94.248

DO YOU WISH TO PLOT OUTFLOW HYDROGRAPH
FOR SEGMENT NO. 3 (Y OR N)? Y

PLEASE BE PATIENT


OUTFLOW HYDROGRAPH FOR SEGMENT NO. 3
FLOW (CFS)
100
90
80
0
4
8
TIME (HOURS)

```
ENTER INFLOW SEGMENTS TO SEGMENT NO.    4 :
(Five values must be entered, if less than five segments are
 confluent with Segment No.    4  then enter zeros to make up
 the difference. One entry to a line.)

? 2
? 3
? 0
? 0
? 0


ROUTE RESERVOIR SEGMENT NO.    4
```

TIME (HRS)	IN (CFS)	OUT (CFS)	VOL (CF)	HEIGHT (FT)
.00	80.000	80.000	522720.0	1.20
.50	80.179	80.031	522853.3	1.20
1.00	119.280	86.777	552239.3	1.27
1.50	122.237	98.414	602932.1	1.38
2.00	125.597	107.148	640976.5	1.47
2.50	129.701	114.821	670973.0	1.54
3.00	130.849	120.942	693281.9	1.59
3.50	131.944	125.082	708374.4	1.63
4.00	132.974	128.004	719023.4	1.65
4.50	129.756	129.335	723875.3	1.66
5.00	130.556	129.660	725060.4	1.66
5.50	134.911	130.877	729497.2	1.67
6.00	138.390	133.164	737831.4	1.69
6.50	131.526	133.874	740421.5	1.70
7.00	124.248	131.503	731778.4	1.68

```
DO YOU WISH TO PLOT OUTFLOW HYDROGRAPH
FOR SEGMENT NO.    4 (Y OR N)? Y

PLEASE BE PATIENT
```

OUTFLOW HYDROGRAPH FOR SEGMENT NO. 4

```
ENTER INFLOW SEGMENTS TO SEGMENT NO.      5 :
(Five values must be entered, if less than five segments are
 confluent with Segment No.    5  then enter zeros to make up
 the difference. One entry to a line.)

? 4
? 0
? 0
? 0
? 0


ROUTE CHANNEL SEGMENT NO.     5

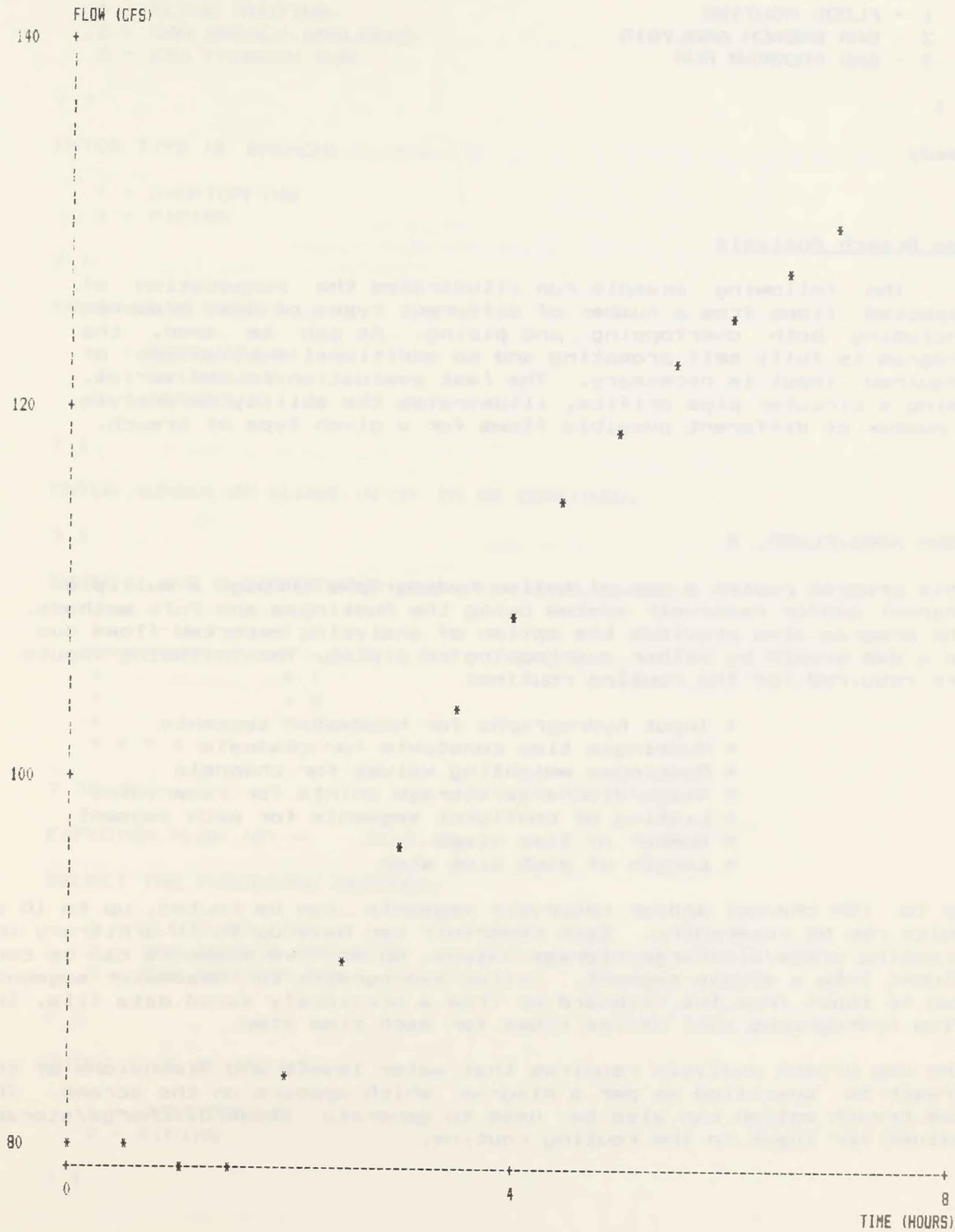
    TIME (HRS)                  IN (CFS)                OUT (CFS)

          .00                    80.000                   80.000
          .50                    80.031                   79.995
         1.00                    86.777                   78.922
         1.50                    98.414                   79.452
         2.00                   107.148                   83.840
         2.50                   114.821                   89.726
         3.00                   120.942                   96.408
         3.50                   125.082                  103.236
         4.00                   128.004                  109.439
         4.50                   129.335                  114.896
         5.00                   129.660                  119.254
         5.50                   130.877                  122.237
         6.00                   133.164                  124.508
         6.50                   133.874                  127.038
         7.00                   131.503                  129.507

DO YOU WISH TO PLOT OUTFLOW HYDROGRAPH
FOR SEGMENT NO.     5 (Y OR N)? Y

PLEASE BE PATIENT
```

OUTFLOW HYDROGRAPH FOR SEGMENT NO. 5



```
SELECT THE PROCEDURE DESIRED:

    1 - FLOOD ROUTING
    2 - DAM BREACH ANALYSIS
    3 - END PROGRAM RUN

? 3

ready
*
```

Dam_Breach_Analysis

The following example run illustrates the computation of expected flows from a number of different types of dam breaches including both overtopping and piping. As can be seen, the program is fully self prompting and no additional explanation of required input is necessary. The last evaluation in the series, using a circular pipe orifice, illustrates the ability to analyze a number of different possible flows for a given type of breach.

*BRN A403/FLOOD, R

This program routes a set of inflow hydrographs through a multiple channel and/or reservoir system using the Muskingam and Puls methods. The program also provides the option of analyzing expected flows due to a dam breach by either overtopping or piping. The following inputs are required for the routing routine:

* Input hydrographs for headwater segments
* Muskingam time constants for channels
* Muskingam weighting values for channels
* Stage/discharge/storage points for reservoirs
* Listing of confluent segments for each segment
* Number of time steps
* Length of each time step

Up to 100 channel and/or reservoir segments can be routed, up to 10 of which can be reservoirs. Each reservoir can have up to 10 arbitrary increasing stage/discharge/storage values. Up to five segments can be confluent into a single segment. Inflow hydrographs to headwater segments can be input from the keyboard or from a previously saved data file. Inflow hydrographs must define flows for each time step.

The dam breach analysis requires that water levels and dimensions of the breach be specified as per a diagram which appears on the screen. The dam breach option can also be used to generate stage/discharge/storage values for input to the routing routine.

```
SELECT THE PROCEDURE DESIRED:

   1 - FLOOD ROUTING
   2 - DAM BREACH ANALYSIS
   3 - END PROGRAM RUN

? 2

ENTER TYPE OF BREACH:

   1 - OVERTOPPING
   2 - PIPING

? 1

ENTER WEIR SHAPE:

   1 - RECTANGULAR
   2 - TRIANGULAR
   3 - PARABOLIC

? 1

ENTER NUMBER OF FLOWS (Q'S) TO BE COMPUTED:

? 1

ENTER L AND D DIMENSIONS (separate with comma):

   |- - - L - - -|
   *=============* - W A T E R   L E V E L
   *             * |
   *             * D
   *             * |
   * * * * * * * * -

? 35,10

EXPECTED FLOW (Q) =     3403.401

SELECT THE PROCEDURE DESIRED:

   1 - FLOOD ROUTING
   2 - DAM BREACH ANALYSIS
   3 - END PROGRAM RUN

? 2

ENTER TYPE OF BREACH:

   1 - OVERTOPPING
   2 - PIPING

? 1
```

```
ENTER WEIR SHAPE:

    1 - RECTANGULAR
    2 - TRIANGULAR
    3 - PARABOLIC

? 2

ENTER NUMBER OF FLOWS (Q'S) TO BE COMPUTED:

? 1

ENTER L AND D DIMENSIONS (separate with comma):

  |- - - - - -  L  - - - - - -|
  *========================* - W A T E R  L E V E L
    *                    *   |
      *                *     |
        *            *       D
          *        *         |
            *    *           |
              *              -

? 35,10

EXPECTED FLOW (Q) =     1279.458

SELECT THE PROCEDURE DESIRED:

    1 - FLOOD ROUTING
    2 - DAM BREACH ANALYSIS
    3 - END PROGRAM RUN

? 2

ENTER TYPE OF BREACH:

    1 - OVERTOPPING
    2 - PIPING

? 1

ENTER WEIR SHAPE:

    1 - RECTANGULAR
    2 - TRIANGULAR
    3 - PARABOLIC

? 3

ENTER NUMBER OF FLOWS (Q'S) TO BE COMPUTED:

? 1
```

```
ENTER L AND D DIMENSIONS (separate with comma)

  | - - - - - - L - - - - - |
  *=======================* - W A T E R   L E V E L
   *                     *   |
    *                   *    D
      *               *      |
             * *             -

? 35,10

EXPECTED FLOW (Q) =     1901.447

SELECT THE PROCEDURE DESIRED:

   1 - FLOOD ROUTING
   2 - DAM BREACH ANALYSIS
   3 - END PROGRAM RUN

? 2

ENTER TYPE OF BREACH:

   1 - OVERTOPPING
   2 - PIPING

? 2

ENTER ORIFICE SHAPE:

   1 - RECTANGULAR PIPE
   2 - CIRCULAR PIPE

? 1

ENTER THE NUMBER OF FLOWS (Q'S) TO BE COMPUTED:

? 1

ENTER L,H, AND D DIMENSIONS (separate with commas):

  ====================== - W A T E R   L E V E L
                         |
                         |
                         D
         - * * * * * * * |
         | *           * |
         H *           * -
         | *           *
         - * * * * * * *
           |- -  L  - -|

? 8,5,10

EXPECTED FLOW (Q) =     604.6275
```

SELECT THE PROCEDURE DESIRED:

    1 - FLOOD ROUTING
    2 - DAM BREACH ANALYSIS
    3 - END PROGRAM RUN

? 2

ENTER TYPE OF BREACH:

    1 - OVERTOPPING
    2 - PIPING

? 2

ENTER ORIFICE SHAPE:

    1 - RECTANGULAR PIPE
    2 - CIRCULAR PIPE

? 2

ENTER NUMBER OF FLOWS (Q'S) TO BE COMPUTED:

? 2

ENTER L AND D DIMENSIONS (separate with comma):

```
 =========================== - W A T E R   L E V E L
                                :
                                :
                 *              D
         *               *      :
                                :
      *                     *   -
         *               *
                 *
      :- - - -   L   - - - -:
```

? 8,10

EXPECTED FLOW (Q) =   759.7562

? 10,10

EXPECTED FLOW (Q) =   1187.119

```
SELECT THE PROCEDURE DESIRED:

   1 - FLOOD ROUTING
   2 - DAM BREACH ANALYSIS
   3 - END PROGRAM RUN

? 3


ready
*
```

V. References

1. Chow, V.T. (ed.), 1964. Handbook of Applied Hydrology. McGraw-Hill, New York.

2. Heggen, R.J., 1983. Flood Routing on a Small Computer. Civil Engineering, March 1983.

3. Linsley, R.K., Jr., Kohler, M.A, and Paulhus, J.L.H., 1975. Hydrology for Engineers. McGraw-Hill Series in Water Res-sources and Environmental Engineering, New York.

4. McCarthy, G.T., 1938. The Unit Hydrograph and Flood Routing. Presented at Conf. North Atl. Div., U.S. Corps Eng., June 1938. See also Engineering Construction: Flood Control, pp. 147-156, The Engineer School, Ft. Belvoir, Va., 1940.

5. National Weather Service, 1979. A Quick Method For Computing Flows From Dam Breaks. National Weather Service, Washington, D.C.

2. BACKWATER CURVE AND VELOCITY PROGRAM

I. Introduction

A backwater curve is the water surface profile of flow in an open channel under gradually varied flow conditions. Gradually varied flow conditions occur when the cross section of flow along the channel varies gradually so that the resulting changes in velocity take place very slowly (1). This program enables the determination of the water surface profile and flow velocity for a fixed flow rate in a trapezoidal, rectangular, or triangular channel by the step method.

II. Program Theory

Changes in the cross section of flow along a channel can result from a change in the geometry of the channel through widening or narrowing or through the introduction of an obstruction such as a dam or another type of flow control structure. The resulting flow profiles can be classified on the basis of the slope of the channel and the relationships between the initial depth at which the profile is to start (Y_O), the normal flow depth (Y_N), and the critical flow depth (Y_C). The normal depth of flow is that obtained under uniform flow conditions for the channel geometry and flow rate given. For the given conditions, the depth of flow which occurs under the energy state which divides tranquil from rapid flow is termed critical depth. At this depth, the Froude number is equal to 1.

The bed slope may be mild, steep, or critical with corresponding M, S, or C profiles (Table 2.1) depending on the relationship of Y_N to Y_C. Each of these profile classifications can be further classified into three subgroups depending upon the relationships between Y_O, Y_N, and Y_C (Table 2.1). The profile classification determines whether the computation proceeds upstream or downstream, incrementing or decrementing from the initial depth until the normal depth is attained.

Table 2.1. - Water surface profiles and depth limits (2).

Type Slope[1]	Type Profile	Depth Relationships	Computational Procedure
Mild ($Y_N > Y_C$)	M1	$Y_O > Y_N$	Proceed upstream, decrementing depth, until normal depth is reached.
	M2	$Y_N > Y_O > Y_C$	Proceed upstream, incrementing depth, until normal depth is reached.
	M3	$Y_C > Y_O$	Proceed downstream, incrementing depth, until normal depth is reached.
Critical ($Y_N = Y_C$)	C1	$Y_O > Y_C$	Proceed upstream, decrementing depth, until normal depth is reached.
	C2	$Y_O = Y_C$	Profile is parallel to bed at $Y_O = Y_C = Y_N$, no procedure.
	C3	$Y_C > Y_O$	Proceed downstream, incrementing depth, until normal depth is reached.
Steep ($Y_C > Y_N$)	S1	$Y_O > Y_C$	Proceed upstream, decrementing depth, until normal depth is reached.
	S2	$Y_C > Y_O > Y_N$	Proceed downstream, decrementing depth, until normal depth is reached.
	S3	$Y_N > Y_O$	Proceed downstream, incrementing depth, until normal depth is reached.

[1] Y_O = Initial depth
Y_N = Normal depth
Y_C = Critical depth

The step method is the simplest procedure for computing backwater curves for a fixed rate of flow (2). The equation of motion for open channel flow can be written:

$$\frac{dE}{dx} = S \qquad [2\text{-}1]$$

where,

E = total energy of flow,
x = distance,
$S = S_o - S_f$ = energy grade line slope,
S_o = bed slope, and
S_f = friction slope.

Under the assumption of steady, uniform flow, the friction slope, S_f , is disregarded. In order to accurately predict a water surface profile, however, we must consider the energy loss due to flowing water. This energy loss is the friction slope term.

If flow rate, Q, channel roughness, n, bed slope, S, and channel geometry are known constants, and if the depth of water at two locations is known or specified, then the distance between the locations, ΔL, can be determined from (3):

$$L = \frac{Y_1 + \alpha\frac{V_1^2}{2g} - Y_2 + \alpha\frac{V_2^2}{2g}}{(S - S_o)}, \qquad [2\text{-}2]$$

where,

$i = 1, 2, 3, \ldots, n,$
Y_i = water depth at point i (ft),
ΔL = distance between points 1 and 2 (ft),
α = kinetic correction factor (often assumed to be 1),
g = gravitational constant (32.2 ft/sec^2),
V_i = water velocity at point i (ft/sec),

$$S_o = \frac{S_1 + S_2}{2}, \text{ and}$$

$$S_i = \left[\frac{Qn}{1.49\, A_i R_i^{2/3}}\right]^2,$$

where,

S_i = water surface slope at point i,
Q = flow (ft^3/sec),
A_i = cross-sectional area of flow at point i (ft^2),
n = Manning's n, and
R_i = hydraulic radius (ft).

Velocities are calculated from:

$$V = \frac{Q}{A}, \qquad [2\text{-}3]$$

where,

V = velocity (ft/sec),
A = cross-sectional area (ft^2), and
Q = flow rate (ft^3/sec).

The step procedure starts with a known depth of flow at the beginning of the channel segment (Y_o) and a given depth increment (I_o). The known channel geometry can then be used in Equations 2-2 and 2-3 to compute L, the length of the portion of the channel segment between Y_o and Y_o +- I_o. By repeating these computations for subsequent incremented or decremented depths, the entire backwater curve can be calculated up to the point where the normal depth is attained.

III. Program Operation / Limitations

After initial data input, the program will calculate the normal and critical depths. The user then inputs the initial depth and depth increment and the program selects and follows the appropriate computational procedure from Table 2.1. Positive distance values in the resulting output indicate steps downstream and negative distance values indicate steps upstream from the location of the initial depth.

In general, as I_o decreases, L decreases and the accuracy of the approximation of the energy slope increases (as does the accuracy of the backwater curve approximation). However, use of a smaller I_o increases computation iterations and the length of the tabular output.

The program is completely menu driven and input of necessary data as well as selection of optional output is prompted as the program is run. The user has the option of producing a plot of the backwater curve as part of the output. A complete listing of the variables used in the program as well as comments describing its operation can be found in the source code.

IV. Example Problem

This example deals with a portion of Donkey Creek which flows through a culvert underneath a road embankment downstream of a trailer park. The culvert tends to become clogged with trash and debris. If this results in raising the water level at the upstream face of the culvert to 2.2 feet, what will the resulting backwater surface profile look like for the mean annual flow ? This portion of the Donkey Creek channel has the following characteristics:

Channel side slope = 4.0 ft/ft
Channel bottom width = 30.0 ft
Channel bed slope = 0.0025 ft/ft
Manning's roughness coefficient = 0.035
Mean annual flow = 30 ft^3/sec

For the initial evaluation a depth increment of 0.1 ft will be used. If, after viewing the results, more accurate values are desired, they can be obtained by using a smaller increment.

```
*BRN A403/BACKH2O, R

This  program uses  the direct step  method to determine a water surface
profile and flow velocities under gradually varied flow conditions for a
fixed  rate of flow in a trapezoidal, rectangular, or triangular channel
by the standard step method.

The program also provides the capability to determine normal flow  depth
or critical flow  depth for  a given channel cross section, Manning's n,
and flowrate. These depths can then be used as starting or ending points
for  determining  downstream or upstream water surface profiles and flow
velocities. This program will also generate a water surface profile plot
when requested by the user.

SELECT THE PROCEDURE DESIRED:

   1 - BACKWATER CURVE
   2 - END PROGRAM RUN

? 1

 *** INITIAL DATA ENTRY FOR NORMAL/CRITICAL DEPTH CALCULATION ***

ENTER FIXED RATE OF DISCHARGE, CFS:
? 30
ENTER CHANNEL BOTTOM WIDTH, FT (ZERO FOR TRIANGULAR CHANNEL):
? 30
ENTER CHANNEL SIDE SLOPE, RISE/RUN, FT/FT(ZERO FOR RECTANGULAR CHANNEL):
? 4
ENTER CHANNEL BED SLOPE, FT/FT:
? .0025
```

```
ENTER MANNING'S COEFFICIENT:
? .035

WAIT WHILE NORMAL DEPTH AND CRITICAL DEPTH ARE COMPUTED

     NORMAL DEPTH =  .63 FT
     CRITICAL DEPTH =  .31 FT

 *** ADDITIONAL DATA ENTRY FOR BACKWATER CURVE CALCULATION ***

ENTER INITIAL DEPTH, FT:
? 2.2
ENTER DEPTH INCREMENT, FT:
? .1

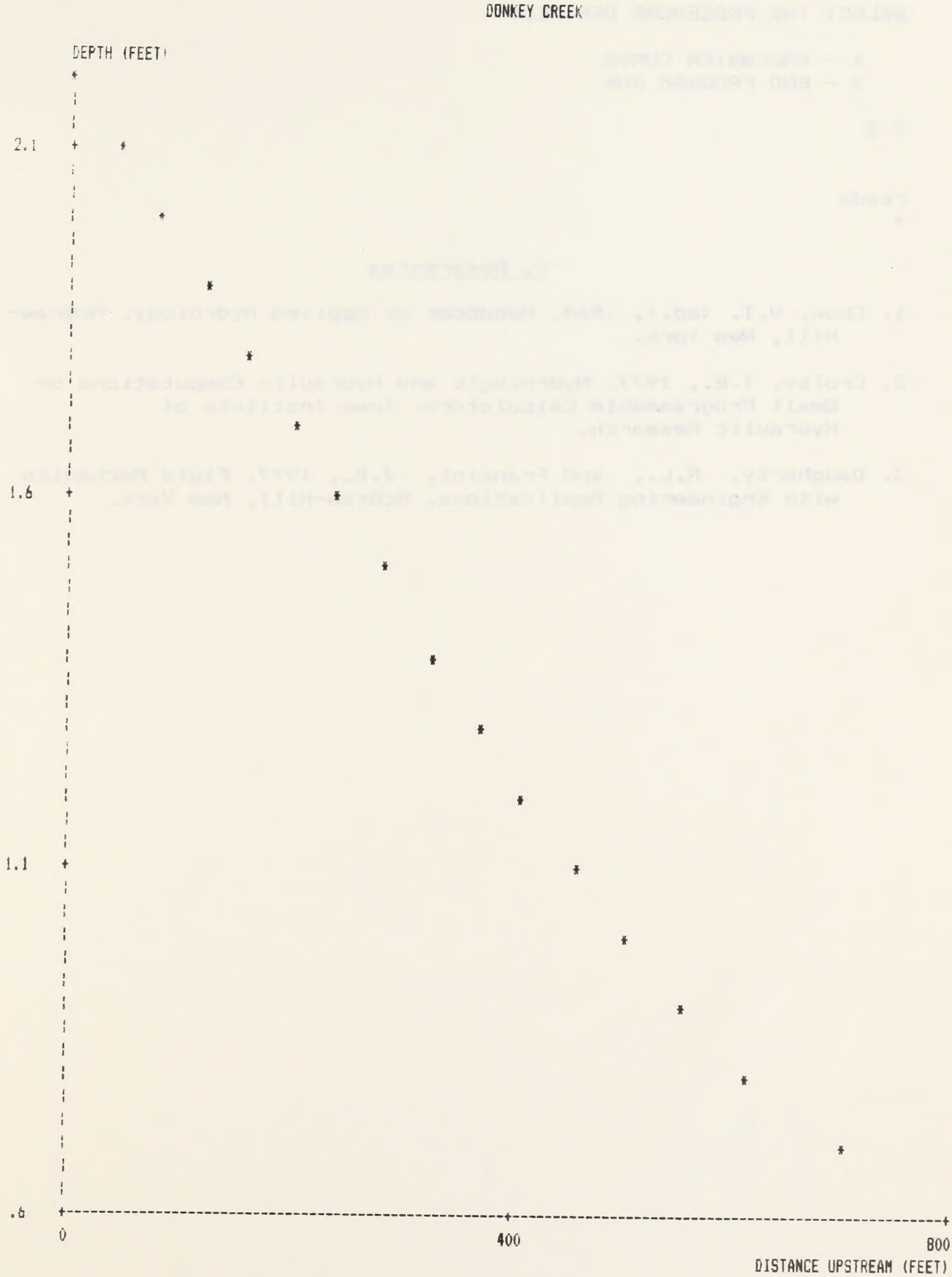
     *** WAIT WHILE BACKWATER CURVE IS CALCULATED ***

   DEPTH     CHG IN DIST       TOT DIST     VEL
==========================================================
     2.20        00.00            00.00        .35
     2.10       -40.47           -40.47        .37
     2.00       -40.56           -81.03        .39
     1.90       -40.67          -121.70        .42
     1.80       -40.82          -162.51        .45
     1.70       -41.00          -203.52        .48
     1.60       -41.25          -244.76        .52
     1.50       -41.57          -286.33        .56
     1.40       -42.02          -328.36        .60
     1.30       -42.65          -371.01        .66
     1.20       -43.57          -414.57        .72
     1.10       -44.97          -459.54        .79
     1.00       -47.24          -506.77        .88
      .90       -51.28          -558.05        .99
      .80       -59.69          -617.74       1.13
      .70       -84.09          -701.82       1.31
      .60      -420.22         -1122.04       1.54

DO YOU WISH TO PLOT BACKWATER CURVE (Y OR N)
? Y

ENTER TITLE FOR PLOT (30 CHARACTERS OR LESS)
? DONKEY CREEK

THIS WILL TAKE SOME TIME
```


DONKEY CREEK
DEPTH (FEET)
2.1
1.6
1.1
.6
0
400
800
DISTANCE UPSTREAM (FEET)

```
SELECT THE PROCEDURE DESIRED:

    1 - BACKWATER CURVE
    2 - END PROGRAM RUN

? 2


ready
*
```

V. References

1. Chow, V.T. (ed.), 1964. Handbook of Applied Hydrology. McGraw-Hill, New York.

2. Croley, T.E., 1977. Hydrologic and Hydraulic Computations on Small Programmable Calculators. Iowa Institute of Hydraulic Research.

3. Daugherty, R.L., and Franzini, J.B., 1977. Fluid Mechanics with Engineering Applications. McGraw-Hill, New York.

SELECT THE PR

1 - BA
2 -

? 2

3. LOG PEARSON TYPE III ANALYSIS

I. Introduction

The determination of the probability of occurence of a flood of given magnitude is an important hydrologic problem. One method of making this determination is a statistical analysis of historical flow data. The log Pearson Type III curve has been selected as a common standard by federal agencies (3).

This program fits a series of events such as peak annual flows, to a log Pearson Type III distribution. Given an event of magnitude X, the program determines the probability of not exceeding X in any given year. The program also determines the recurrence interval (in years) of X.

II. Program Theory

The log Pearson Type III distribution is commonly used for predicting flood recurrence intervals. When this distribution is used it is assumed that the logarithms of the individual events can be fit to a type of curve originally derived by Karl Pearson (4). The distribution is actually a three-parameter Gamma distribution that uses the logarithms of the individual events as the random variate.

The Pearson Type III probability density function is:

F(y) = probability density function

$$= \frac{1}{\beta\Gamma(\alpha)} t^{\alpha-1} e^{-t} \qquad [3\text{-}1]$$

where,

$$t = \frac{y - c}{\beta},$$

$$\alpha = \left[\frac{2}{\Psi}\right]^2,$$

$$\beta = \frac{s\Psi}{2},$$

$$c = \frac{y - 2s}{\Psi}, \text{ and}$$

y = mean of y series,
s = standard deviation of y series,
Ψ = skew coefficient of y series, and

$\Gamma(\alpha)$ = gamma function.

By integrating the probability density function for a given recurrence interval, Y, one can derive an equation of the form:

$$y = \bar{y} + sK \qquad [3\text{-}2]$$

where,

y_Y = event of recurrence interval Y, and

K = a function of skew and exceedence probability.

Table 3.1 enables one to easily determine K given probability (or recurrence interval) and skew.

Given a series (x series) of events $x_1, x_2, x_3, \ldots, x_n$, the program computes the series (y series) $y_1, y_2, y_3, \ldots, y_n$ by taking the natural logarithm of each x. The normal statistical parameters y, s, and are calculated using the y values. The Pearson Type III parameters , , and c are computed from $\bar{y}$, s, and Ψ. The probability of an event, y , can be calculated:

$$P(x < x_Y) = \left[\frac{a + m}{2\pi}\right]^{1/2} * \frac{(a + m - 1)!\alpha}{\alpha!} * \left[\frac{t}{\alpha + m}\right]^{\alpha}$$

$$* \left[\frac{1}{\alpha + m}\right]^{m} \exp\left[-t_Y + \alpha + m - \frac{1}{12(\alpha + m)}\right.$$

$$\left. + \frac{1}{360(\alpha + m)^3}\right] * \sum_{n=0}^{p} \frac{(t_Y)^n}{\alpha(\alpha + 1)\ldots(\alpha + n)} \qquad [3\text{-}3]$$

where,

$P(x < x_Y)$ = the probability that any randomly observed event x, will be less than or equal to the event x_Y that has a recurrence interval of Y years,

TABLE 3.1. - K values for use with Log Pearson Type III Distribution.
Probability, $P(y \leq y_\gamma)$
[Recurrence Interval (yrs) in Parenthesis]

Skew Ψ	0.01 (1.01)	0.05 (1.05)	0.10 (1.11)	0.20 (1.25)	0.50 (2.0)	0.80 (5.0)	0.90 (10.0)	0.96 (25.0)	0.98 (50.0)	0.99 (100.0)	0.995 (200.0)
3.0	-.667	-.665	-.660	-.636	.396	.420	1.180	2.278	3.152	4.051	4.970
2.9	-.690	-.688	-.681	-.651	-.390	.440	1.195	2.277	3.134	4.013	4.905
2.8	-.714	-.711	-.702	-.666	-.384	.460	1.210	2.275	3.114	3.973	4.847
2.7	-.740	-.736	-.724	-.681	-.376	.479	1.224	2.272	3.093	3.932	4.783
2.6	-.769	-.762	-.747	-.696	-.368	.499	1.238	2.267	3.071	3.889	4.718
2.5	-.799	-.790	-.771	-.711	-.360	.518	1.250	2.262	3.048	3.845	4.652
2.4	-.832	-.819	-.795	-.725	-.351	.537	1.262	2.256	3.023	3.800	4.584
2.3	-.867	-.850	-.819	-.739	-.341	.555	1.274	2.248	2.997	3.753	4.515
2.2	-.905	-.882	-.844	-.752	-.330	.574	1.284	2.240	2.970	3.705	4.444
2.1	-.946	-.914	-.869	-.765	-.319	.592	1.294	2.230	2.942	3.656	4.372
2.0	-.990	-.949	-.895	-.777	-.307	.609	1.302	2.219	2.912	3.605	4.298
1.9	-1.037	-.984	-.920	-.788	-.294	.627	1.310	2.207	2.881	3.553	4.223
1.8	-1.087	-1.020	-.945	-.799	-.282	.643	1.318	2.193	2.848	3.499	4.147
1.7	-1.140	-1.056	-.970	-.808	-.268	.660	1.324	2.179	2.815	3.444	4.069
1.6	-1.197	-1.093	-.994	-.817	-.254	.675	1.329	2.163	2.780	3.388	3.990
1.5	-1.256	-1.131	-1.018	-.825	-.240	.690	1.333	2.146	2.743	3.330	3.910
1.4	-1.318	-1.168	-1.041	-.832	-.225	.705	1.337	2.128	2.706	3.271	3.828
1.3	-1.383	-1.206	-1.064	-.838	-.210	.719	1.339	2.108	2.666	3.211	3.745
1.2	-1.449	-1.243	-1.086	-.844	-.195	.732	1.340	2.087	2.626	3.149	3.661
1.1	-1.518	-1.280	-1.107	-.848	-.180	.745	1.341	2.066	2.585	3.087	3.575
1.0	-1.588	-1.317	-1.128	-.852	-.164	.758	1.340	2.043	2.542	3.022	3.489
.9	-1.660	-1.353	-1.147	-.854	-.148	.769	1.339	2.018	2.498	2.957	3.401
.8	-1.733	-1.388	-1.166	-.856	-.132	.780	1.336	1.993	2.453	2.891	3.312
.7	-1.806	-1.423	-1.183	-.857	-.116	.790	1.333	1.967	2.407	2.824	3.223
.6	-1.880	-1.458	-1.200	-.857	-.099	.800	1.328	1.939	2.359	2.755	3.132
.5	-1.955	-1.491	-1.216	-.856	-.803	.808	1.323	1.910	2.311	2.686	3.041
.4	-2.029	-1.524	-1.231	-.855	-.066	.816	1.317	1.880	2.261	2.615	2.949
.3	-2.104	-1.555	-1.245	-.853	-.050	.824	1.309	1.849	2.211	2.544	2.856
.2	-2.178	-1.586	-1.258	-.850	-.033	.830	1.301	1.818	2.159	2.472	2.763
.1	-2.252	-1.616	-1.270	-.846	-.017	.836	1.292	1.785	2.107	2.400	2.670
.0	-2.236	-1.645	-1.282	-.842	.000	.842	1.282	1.751	2.054	2.326	2.576
-.1	-2.400	-1.673	-1.292	-.836	.017	.846	1.270	1.716	2.000	2.252	2.482
-.2	-2.472	-1.700	-1.301	-.830	.033	.850	1.258	1.680	1.945	2.178	2.388
-.3	-2.544	-1.726	-1.309	-.824	.050	.853	1.245	1.643	1.890	2.104	2.294
-.4	-2.615	-1.750	-1.317	-.816	.066	.855	1.231	1.606	1.834	2.029	2.201
-.5	-2.686	-1.774	-1.323	-.808	.083	.856	1.216	1.567	1.777	1.955	2.108
-.6	-2.755	-1.797	-1.328	-.800	.099	.857	1.200	1.528	1.720	1.880	2.016
-.7	-2.284	-1.819	-1.333	-.790	.116	.857	1.183	1.488	1.663	1.806	1.926
-.8	-2.891	-1.839	-1.336	-.780	.132	.856	1.166	1.448	1.606	1.733	1.837
-.9	-2.957	-1.858	-1.339	-.769	.148	.854	1.147	1.407	1.549	1.660	1.749
-1.0	-3.022	-1.877	-1.340	-.758	.164	.852	1.128	1.366	1.492	1.588	1.664
-1.1	-3.087	-1.894	-1.341	-.745	.180	.848	1.107	1.324	1.435	1.518	1.581
-1.2	-3.149	-1.910	-1.340	-.732	.195	.844	1.086	1.282	1.379	1.449	1.501
-1.3	-3.211	-1.925	-1.339	-.719	.210	.838	1.064	1.240	1.324	1.383	1.424
-1.4	-3.271	-1.938	-1.337	-.705	.225	.832	1.041	1.198	1.270	1.318	1.351

(Continued on next page.)

TABLE 3.1. - K values for use with Log Pearson Type III Distribution (cont.).
Probability, $P(y \leq y_{\gamma})$
[Recurrence interval (yrs) in Parenthesis]

Skew Ψ	0.01 (1.01)	0.05 (1.05)	0.10 (1.11)	0.20 (1.25)	0.50 (2.0)	0.80 (5.0)	0.90 (10.0)	0.96 (25.0)	0.98 (50.0)	0.99 (100.0)	0.995 (200.0)
-1.5	-3.330	-1.951	-1.333	-.690	.240	.825	1.018	1.157	1.217	1.256	1.282
-1.6	-3.388	-1.962	-1.329	-.675	.254	.817	.994	1.116	1.166	1.197	1.216
-1.7	-3.444	-1.972	-1.324	-.660	.268	.808	.970	1.075	1.116	1.140	1.155
-1.8	-3.499	-1.981	-1.318	-.643	.282	.799	.945	1.035	1.069	1.087	1.097
-1.9	-3.553	-1.989	-1.310	-.627	.294	.788	.920	.996	1.023	1.037	1.044
-2.0	-3.605	-1.996	-1.302	-.609	.307	.777	.895	.959	.980	.990	.995
-2.1	-3.656	-2.001	-1.294	-.592	.319	.765	.869	.923	.939	.946	.949
-2.2	-3.705	-2.006	-1.284	-.574	.330	.752	.844	.888	.900	.905	.907
-2.3	-3.753	-2.009	-1.274	-.555	.341	.739	.819	.855	.864	.867	.869
-2.4	-3.800	-2.011	-1.262	-.537	.351	.725	.795	.823	.830	.832	.833
-2.5	-3.845	-2.012	-1.250	-.518	.360	.711	.771	.793	.798	.799	.800
-2.6	-3.889	-2.013	-1.238	-.499	.368	.696	.747	.764	.768	.769	.769
-2.7	-3.932	-2.012	-1.224	-.479	.376	.681	.724	.738	.740	.740	.741
-2.8	-3.973	-2.010	-1.210	-.460	.384	.666	.702	.712	.714	.714	.714
-2.9	-4.013	-2.007	-1.195	-.440	.390	.651	.681	.683	.689	.690	.690
-3.0	-4.051	-2.003	-1.180	-.420	.396	.636	.660	.666	.666	.667	.667

$$t = \frac{y_{\gamma} - c}{\beta} = \gamma\text{-quantile point for } t_{\gamma},$$

m = a positive integer, and
p = a positive integer.

The accuracy of the determination increases as p and m increase. To hold the number of computations to a reasonable level the values are chosen such that m is less than or equal to five and p is sufficiently large to ensure that the summation in the series expansion is accurate to over ten places.

This program is based on a program from *Hydrologic and Hydraulic Computations on Small Programmable Calculators* by Thomas E. Croley II (2). For a complete discussion of the mathematics involved, this reference is highly recommended. A brief description of the Pearson Type III probability density function can be found in the *Handbook of Mathematical Functions* (1).

III. Program Operation / Limitations

A maximum of 200 flows can be input for a single analysis. This amount was considered to be adequate for flow records for the vast majority of gaging stations (i.e., there are few stations in existance with periods of record longer than 200 years). This limit can be increased, however, by increasing the size of the arrays in the dimension statements for the appropriate variables.

The program allows entered flows to be saved to a disk file and then recalled and edited or added to during later runs. The program also allows entered flows to be reviewed and edited prior to the performance of the analysis. A plot of flows versus computed return periods can also be generated. The program is completely menu driven and input of necessary data as well as selection of optional output is prompted as the program is run. A complete listing of the variables used in the program as well as comments describing its operation can be found in the source code.

IV. Example Problem

This example deals with flow data from a USGS gaging station on Donkey Creek in the northern Powder River Basin, Wyoming. The objective is to evaluate the flows associated with a number of different return periods in order to determine the storage and spillway capacities for a flood control reservoir to be located in the Donkey Creek drainage. A total of 31 annual peak flows were available for the analysis:

YEAR	FLOW (cfs)	YEAR	FLOW (cfs)
1953	108.0	1970	567.0
1954	53.6	1971	122.0
1955	585.0	1972	151.0
1956	98.1	1973	244.0
1957	40.6	1974	400.0
1958	472.0	1975	245.0
1959	96.5	1976	114.0
1960	217.0	1977	659.0
1961	42.7	1978	132.0
1962	208.0	1979	44.0
1963	143.0	1980	72.5
1964	93.7	1981	135.0
1965	398.0	1982	635.0
1966	298.0	1983	508.0
1967	248.0		
1968	441.0		
1969	386.0		

*BRN A403/PEARSON, R

This program fits a series of flow events such as peak annual flows to a Log Pearson Type III distribution. This distribution is commonly used to predict flood recurrence intervals. Initial data input for a given gaging station is the number of measured peak flows and the amount of each flow in cubic feet per second (CFS). If flow data for a particular gaging station has been previously analyzed, and the

resulting output saved to a disk file, the disk file may be called up at the user's request in order to avoid re-inputting all of the flow amounts. Previously entered flows may also be edited and added to during later program runs. The program is limited to 200 flows per gaging station. The program begins by asking for the name of the file the output is to be written to. If an output file has been previously generated, the same file name may be used, or a different file name may be used to separate the results.

```
SELECT THE PROCEDURE DESIRED:

   1 - PEARSON
   2 - END PROGRAM RUN

? 1

INPUT NAME OF GAGING STATION (30 CHARACTERS OR LESS)
? DONKEY CREEK

DO YOU WISH TO INPUT FLOW DATA FROM THE KEYBOARD OR FROM A PREVIOUSLY
GENERATED DATA FILE (1 OR 2) ?

     1 - KEYBOARD
     2 - FILE

? 1

HOW MANY FLOWS IN FLOOD SERIES ? 31

ENTER EACH FLOW:

    1  ? 108
    2  ? 536
    3  ? 585
    4  ? 98.1
    5  ? 40.6
    6  ? 472
    7  ? 96.5
    8  ? 217
    9  ? 42.7
   10  ? 208
   11  ? 143
   12  ? 93.7
   13  ? 398
   14  ? 298
   15  ? 248
   16  ? 441
   17  ? 386
   18  ? 567
   19  ? 122
   20  ? 151
   21  ? 244
   22  ? 400
   23  ? 245
   24  ? 114
```

```
  25  ? 659
  26  ? 132
  27  ? 44
  28  ? 72.5
  29  ? 135
  30  ? 635
  31  ? 508

SELECT ONE FROM MENU BELOW:

     1 - EDIT FLOWS
     2 - COMPUTE RETURN PERIOD FOR A GIVEN FLOW
     3 - COMPUTE A FLOW FOR A GIVEN RETURN PERIOD
     4 - GENERATE A FLOOD FREQUENCY PLOT
     5 - EVALUATE NEW SET OF FLOWS
     6 - END PROGRAM RUN
? 1

      1   108.00     2  536.00     3  585.00     4    98.10
      5    40.60     6  472.00     7   96.50     8   217.00
      9    42.70    10  208.00    11  143.00    12    93.70
     13   398.00    14  298.00    15  248.00    16   441.00
     17   386.00    18  567.00    19  122.00    20   151.00
     21   244.00    22  400.00    23  245.00    24   114.00
     25   659.00    26  132.00    27   44.00    28    72.50
     29   135.00    30  635.00    31  508.00

     * NOTE NUMBER OF ANY FLOW AMOUNT WHICH IS INCORRECT !

DO YOU WISH TO CHANGE, ADD TO, OR LEAVE AS IS THE PREVIOUSLY
ENTERED FLOW AMOUNTS (1, 2 OR 3) ?

     1 - CHANGE
     2 - ADD TO
     3 - LEAVE AS IS

? 1

ENTER THE NUMBER OF THE FLOW YOU WISH TO CHANGE
? 2

PRESENT VALUE OF FLOW NO.    2 =    536  CFS
ENTER NEW VALUE
? 53.6
NEW VALUE OF FLOW NO.    2  =  53.6  CFS

DO YOU WISH TO CHANGE, ADD TO, OR LEAVE AS IS THE PREVIOUSLY
ENTERED FLOW AMOUNTS (1, 2 OR 3) ?

     1 - CHANGE
     2 - ADD TO
     3 - LEAVE AS IS

? 3
```

```
SELECT ONE FROM MENU BELOW:

     1 - EDIT FLOWS
     2 - COMPUTE RETURN PERIOD FOR A GIVEN FLOW
     3 - COMPUTE A FLOW FOR A GIVEN RETURN PERIOD
     4 - GENERATE A FLOOD FREQUENCY PLOT
     5 - EVALUATE NEW SET OF FLOWS
     6 - END PROGRAM RUN
? 2

ENTER DESIRED FLOW VALUE
? 1199
PROBABILITY THAT 1199 CFS WILL NOT BE EXCEEDED =  .9900085
RETURN PERIOD FOR  1199  CFS =   100.0853  YEARS

SELECT ONE FROM MENU BELOW:

     1 - EDIT FLOWS
     2 - COMPUTE RETURN PERIOD FOR A GIVEN FLOW
     3 - COMPUTE A FLOW FOR A GIVEN RETURN PERIOD
     4 - GENERATE A FLOOD FREQUENCY PLOT
     5 - EVALUATE NEW SET OF FLOWS
     6 - END PROGRAM RUN
? 2

ENTER DESIRED FLOW VALUE
? 1500
PROBABILITY THAT 1500 CFS WILL NOT BE EXCEEDED =  .9958601
RETURN PERIOD FOR  1500  CFS =    241.5543  YEARS

SELECT ONE FROM MENU BELOW:

     1 - EDIT FLOWS
     2 - COMPUTE RETURN PERIOD FOR A GIVEN FLOW
     3 - COMPUTE A FLOW FOR A GIVEN RETURN PERIOD
     4 - GENERATE A FLOOD FREQUENCY PLOT
     5 - EVALUATE NEW SET OF FLOWS
     6 - END PROGRAM RUN
? 3

OBTAIN K VALUE FROM TABLE 1 USING SKEW =  -.2012941 AND
DESIRED RETURN PERIOD (OR PROBABILITY).

ENTER K VALUE
? 1.680

FLOW =    784.2545  CFS
```

```
SELECT ONE FROM MENU BELOW:

     1 - EDIT FLOWS
     2 - COMPUTE RETURN PERIOD FOR A GIVEN FLOW
     3 - COMPUTE A FLOW FOR A GIVEN RETURN PERIOD
     4 - GENERATE A FLOOD FREQUENCY PLOT
     5 - EVALUATE NEW SET OF FLOWS
     6 - END PROGRAM RUN
? 3

OBTAIN K VALUE FROM TABLE 1 USING SKEW =   -.2012941 AND
DESIRED RETURN PERIOD (OR PROBABILITY).

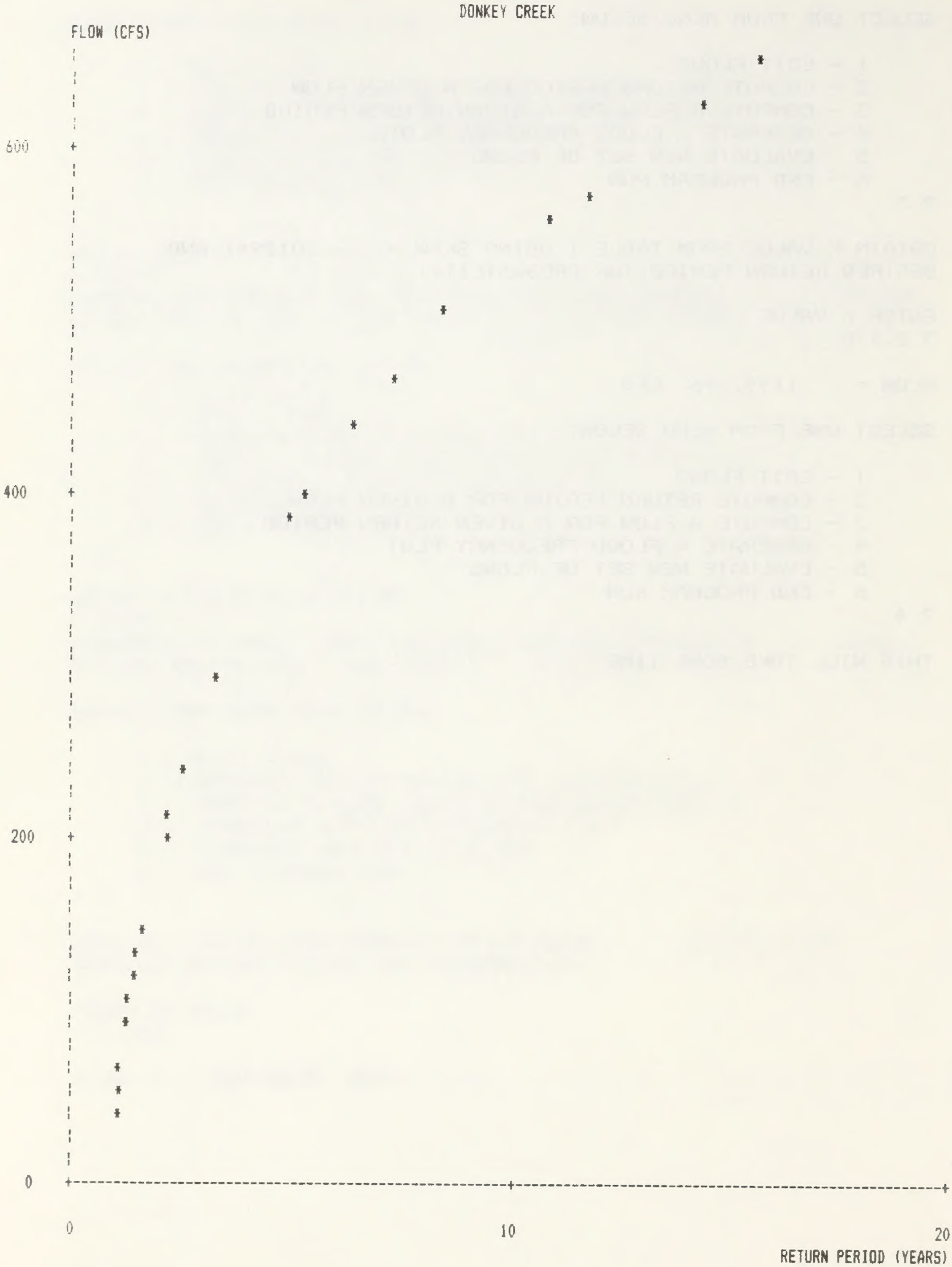
ENTER K VALUE
? 2.178

FLOW =     1199.296  CFS

SELECT ONE FROM MENU BELOW:

     1 - EDIT FLOWS
     2 - COMPUTE RETURN PERIOD FOR A GIVEN FLOW
     3 - COMPUTE A FLOW FOR A GIVEN RETURN PERIOD
     4 - GENERATE A FLOOD FREQUENCY PLOT
     5 - EVALUATE NEW SET OF FLOWS
     6 - END PROGRAM RUN
? 4

THIS WILL TAKE SOME TIME
```


DONKEY CREEK
FLOW (CFS)
600
400
200
0
0
10
20
RETURN PERIOD (YEARS)

```
SELECT ONE FROM MENU BELOW:

     1 - EDIT FLOWS
     2 - COMPUTE RETURN PERIOD FOR A GIVEN FLOW
     3 - COMPUTE A FLOW FOR A GIVEN RETURN PERIOD
     4 - GENERATE A FLOOD FREQUENCY PLOT
     5 - EVALUATE NEW SET OF FLOWS
     6 - END PROGRAM RUN
? 6

DO YOU WISH TO SAVE ENTERED FLOWS IN A DISK FILE ? (Y OR N)
? Y

ENTER NAME OF OUTPUT FILE (8 CHARACTERS OR LESS)
? DONCRK


ready
*
```

V. References

1. Abramowitz, M., and Stegun, I.E., 1970. Handbook of Mathematical Functions. Dover Publications, New York.

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4. Pearson, K., 1930. Tables for Statisticians and Biometricians, 3rd Edition. Cambridge University Press, London.

5. Remenievas, G., 1967. "Statistical Methods of Flood Frequency Analysis", in Assessment of the Magnitude and Frequency of Flood Flows, Water Resources Series 30, United Nations World Meteorological Organization, New York, pp. 50-108.

4. UNIVERSAL SOIL LOSS EQUATION

I. Introduction

This program generally follows the procedure described in *Predicting Rainfall Erosion Losses - A Guide to Conservation Planning, USDA Agriculture Handbook No. 537*(6). The objective of this program is to calculate average erosion from an area. The equation on which the program is based was designed to predict long-term soil losses from sheet and rill erosion on given field slopes under specified land use and management. The program uses, as does the original equation, factors related to climate, soil, topography, and crop management. It is not intended here to provide a detailed discussion of the equation. Several good, readily obtainable references are mentioned in the following discussion and included in the list of references.

II. Program Theory

The Universal Soil Loss Equation (USLE) is an empirically developed formula used to estimate soil loss on agricultural lands. Although it was developed for eastern crop lands, it is potentially a useful tool for predicting erosion under a variety of land uses.

The USLE only accounts for sheet and rill erosion. No erosion from gullying is considered. In the western U.S. gully erosion is often the principal source of sediment. Thus, the USLE may not represent a comprehensive total of all erosion from an area.

The USLE only considers average erosion, not the sediment delivery ration to a stream channel. When applying the USLE to estimate sediment impacts on surface water quality, the total erosion computed by the USLE must be adjusted with the appropriate sediment delivery ratio.

The USLE is:

$$\text{USLE} = (R)\ (K)\ (LS)\ (C)\ (P) \qquad [4\text{-}1]$$

where,

R = the rainfall factor, is the number of erosion index units in a normal year's rain; the erosion index is a measure of the erosive force of specific rainfall,

K = the soil erodibility factor, is the erosion rate per unit of erosion index for a specific soil and a standard set of conditions,

LS = the slope length and topographic factor,

C = crop management factor is the ratio of soil loss from a field with a specified crop management to a fallow soil, and

P = erosion control practice factor, is the ratio of soil loss, under specified erosion control practices, to a soil plowed in straight furrows up and down the slope.

When working with the USLE, special attention must be paid to the R factor which is a measurement of the kinetic energy of expected rainstorms for a specific geographical area. The R value for a given locality in the Western U.S. can be found on figure 1 of *Preliminary Guidance for Estimating Erosion on Areas Disturbed by Surface Mining in the Interior Western United States* (2).

The R factor for the western U.S. can also be estimated from the 2-year, 6-hour rainfall by using the equation (2):

$$R = 27.38\ P^{2.17} \qquad [4\text{-}2]$$

where,

R = rainfall factor in USLE, and
P = inches of rainfall in the 2-year, 6-hour storm.

The 2-year, 6-hour storm can be found in the appropriate volume (one volume for each state) of *NOAA Atlas 2, Precipitation Frequency Atlas of the Western United States* (3).

The R factor does not consider erosion caused by snowmelt runoff. Limited data suggests that R for the period of snowmelt can be estimated as 1.5 times the local December-March precipitation, in inches of water. This number is then added to the R computed for rainfall to give the total yearly R values.

R factors can also be estimated for part of the year. The monthly distribution of R is known for several locations in the western U.S. Table 7 of *Predicting Rainfall Erosion Losses* (6) shows the monthly distribution of R at selected western locations.

Some soils erode more readily than others and this characteristic is accounted for in the USLE by the K factor. Appendix A of *Preliminary Guidance for Estimating Erosion on Areas Disturbed by Surface Mining Activities in the Interior Western United States* (2) gives K factors for all established soil series in the western U.S. The K factor can also be estimated with the following equation (6):

$$K = (2.1 \times 10^{-6})(M^{1.14})(12-a) + .0325(b-2) + .025(c-3) \qquad [4\text{-}3]$$

where,

M = particle size parameter, defined as [(% silt + very fine sand) x (100 - % clay)],
a = % organic matter,
b = soil structure code, and
c = permeability class.

When b is:	Structure is:
1	very fine granular
2	fine granular
3	medium or coarse granular
4	blocky, platy, or massive

When c is:	Permeability is:
1	rapid
2	moderate to rapid
3	moderate
4	slow to moderate
5	slow
6	very slow

This equation is only accurate when:

1) % silt plus very fine sand < 70%, and
2) % organic matter < 4%.

The length and steepness of slopes in an area are important determinants of the rate of erosion. The LS factor in the USLE accounts for the topographic influence of relief on the rate of erosion. For uniform slopes, LS is determined from the following equation (6):

$$LS = (\lambda/72.6)^m \; ((65.41 * \sin\theta^2 + (4.56 * \sin\theta) + .065) \qquad [4-4]$$

where,

LS = slope length and gradient factor,
λ = length of slope (ft),
θ = angle of slope - rise/run, and
m = 0.5 if slope > or = 5.0%,
0.4 if slope > or = 3.5% and < 5.0%,
0.3 if slope > or = 1.0% and < 3.5%, or
0.2 if slope < 1.0%.

This equation is solved by assuming:

$$\theta = \tan\theta = \sin\theta .$$

This is true for small θ. At a slope of as much as 20 percent, the error in the calculated LS factor is about three percent.

For irregular slopes (where θ changes), the LS factor can be computed by first dividing the slope into equal length segments of constant slope. The LS factor for each segment is then computed. The following equation is used to adjust the LS factor of each segment:

$$x = \frac{I^{m+1} - (I-1)^{m+1}}{N^{m+1}} \qquad [4\text{-}5]$$

where,

- x = segment adjustment factor,
- I = segment sequence number (segment number 1 is always at the top of the slope),
- N = number of segments, and
- m = 0.5 if slope > or = 5.0%,
  0.4 if slope > or = 3.5% and < 5.0%,
  0.3 if slope > or = 1.0% and < 3.5%, or
  0.2 if slope < 1.0%.

The adjusted segment LS factors are then summed to give the total LS factor for the slope.

The C factor is the ratio of soil loss cropped under specified conditions to the corresponding loss from clean-tilled fallow soil. Numerous references are available to help estimate the cropping factor. See Tables 2, 3, 4, and 5 in *Preliminary Guidance for Estimating Erosion on Areas Disturbed by Surface Mining Activities in the Interior Western United States* (2), Tables 2, 3, and 4 in *Procedure for Computing Sheet and Rill Erosion on Project Areas, USDA-SCS Technical Release No. 51* (1), and Tables 5, 8, 9, 10, 11, and 12 in *Predicting Rainfall Erosion Losses - A Guide to Conservation Planning*, (6). Table 10 from the later is reproduced below as Table 4-1 and is recommended as a source for C values.

TABLE 4-1.- Factor C for permanent pasture, range, and idle land (6)[1].

VEGETATIVE CANOPY		COVER THAT CONTACTS THE SOIL SURFACE						
Type and Height[2]	Percent Cover[3]	Type[4]	Percent Ground Cover 0	20	40	60	80	95+
No appreciable canopy.		G	0.45	0.20	0.10	0.042	0.013	0.003
		W	.45	.24	.15	.091	.043	.011
Tall weeds or short brush with average drop fall height of 20 in.	25	G	.36	.17	.09	.038	.013	.003
		W	.36	.20	.13	.083	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.076	.039	.011
	75	G	.17	.10	.06	.032	.011	.003
		W	.17	.12	.09	.068	.038	.011
Appreciable brush or bushes, with average drop fall height of 6.5 ft.	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.087	.042	.011
	50	G	.34	.16	.08	.038	.012	.003
		W	.34	.19	.13	.082	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.078	.040	.011
Trees, but no appreciable low brush. Average drop fall height of 13 ft.	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.089	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.087	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.084	.041	.011

[1] The listed C values assume that the vegetation and mulch are randomly distributed over the entire area.

[2] Canopy height is measured as the average fall height of water drops falling from the canopy to the ground. Canopy effect is inversely proportional to drop fall height and is negligible if fall height exceeds 33 ft.

[3] Portion of total-area surface that would be hidden from view by canopy in a vertical projection (a bird's-eye view).

[4] G: cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 in. deep.

W: cover at surface is mostly broadleaf herbaceous plants (as weeds with little lateral-root network near the surface) or undecayed residues or both.

The P Factor measures the influence of various erosion control practices such as contour plowing and cultivated strips along the contour, on soil loss. For areas without these factors, (bare soil, rangeland, reclaimed land) set P = 1.0. Table 6 of *Preliminary Guidance for Estimating Erosion on Areas Disturbed by Surface Mining Activities in the Interior Western United States*, (2) shows appropriate P values.

Terracing does not impact the P factor in the USLE. Terracing is accounted for in the LS factor by a reduction in slope length (L is the length of a single terrace).

III. Program Operation / Limitations

The USLE is an erosion model designed to compute longtime average soil losses from sheet and rill erosion under specified conditions. It is also useful for construction sites and other non-agricultural conditions, but it does not predict deposition and does not compute sediment yields from gully, streambank, and streambed erosion (6). The accuracy of the estimates resulting from the use of the USLE are dependent upon the accuracy of the estimates made for the various factors contained in the model. An excellent starting point for a discussion of significant limitations in the available data for each of the factors is USDA Agriculture Handbook 537 entitled, *Predicting Rainfall Erosion Losses - A Guide to Conservation Planning*(6).

The program allows soil losses to be computed for a single basin or to be cummulated for a series of basins. There is no practical limit to the number of basins which can assessed in a given run. The program also allows a sediment delivery ratio to be applied to the calculated soil losses in order to estimate the amount of sediment actually being delivered to the stream channel. The sediment delivery ratio applied is, of course, dependent upon the user's knowledge of the basin or basins being analyzed.

The program is totally menu driven and input of the necessary data is throughly prompted as the program is run. Care should be taken that the desired values have been typed at the keyboard for each factor before the value is entered into the program by hitting the return key. This will save having to re-enter all values for a given run and will maintain the accuracy of the cummulative soil loss result. A complete listing of the variables used in the program as well as comments describing its operation can be found in the source code.

IV. Example Problem

This example uses information from a Mine Permit Application for the Rawhide coal mine in Wyoming's Powder River Basin. The objective is to estimate the average annual erosion rate from a disturbed area near the mine in order to help in determining the required storage capacity for the Rawhide Mine Main Reservoir. The following information was supplied in the permit application:

R = 50.0
K = 0.31
Lo = 1750.0 ft
So = 7.5%
C = 0.45
P = 1.0
Disturbed Area = 5.01 acres

*BRN A403/USLE, R

This program generally follows the procedure described in 'Predicting Rainfall Erosion Losses - A Guide to Conservation Planning', USDA, Agriculture Handbook No. 537, 1978.

The program uses the Universal Soil Loss Equation (USLE) to estimate soil loss from a given acreage of land. The USLE is an empirically developed formula intended to estimate soil loss on agricultural lands. The USLE only accounts for sheet and rill erosion. No erosion from gullying is considered. In the western U.S., gully erosion is often the principal source of sediment. Thus, the USLE may not represent a comprehensive total of erosion from an area in the western U.S. The USLE only considers average erosion, not the sediment delivery ratio to a stream channel. When applying the USLE to estimate sediment impacts on surface water quality, the total erosion computed by the USLE must be adjusted with the appropriate sediment delivery ratio. This program allows the option of a sediment delivery ratio to be input after the amount of average soil erosion has been calculated. To continue the program run, select '1' from the following menu:

1 - COMPUTE A SOIL LOSS ESTIMATE FOR A NEW BASIN OR GROUP OF BASINS
2 - COMPUTE A SOIL LOSS ESTIMATE TO BE ADDED TO PREVIOUS ESTIMATE
3 - COMPUTE SEDIMENT YIELD
4 - END PROGRAM RUN

? 1

TITLE FOR THE OUTPUT FROM THIS RUN? RAWHIDE MAIN RESERVOIR

The USLE accounts for soil erosion through the application of a number of factors. The form of the equation is:

USLE = (R) (K) (LS) (C) (P)

R = Rainfall Factor
K = Soil Erodibility Factor
LS = Slope Length and Topographic Factor
C = Crop Management Factor
P = Erosion Control Practice Factor

R, the rainfall factor, is the number of erosion index units in a normal year's rain. The erosion index is a measure of the erosive force of specific rainfall. The R factor measures the kinetic energy of expected rainstorms for a specific geographical area. The R factor for the western U.S. can be estimated from the 2-year, 6-hour rainfall. Select one from the following list:

1 - ENTER R DIRECTLY
2 - COMPUTE R FROM 2-YEAR, 6-HOUR STORM

? 1

R? 50

K, the soil erodibility factor, is the erosion rate per unit of erosion index for a specific soil and a standard set of conditions. The K factor can be estimated from a particle size parameter, % organic matter, a soil structure code, and a permeability class. This estimation is only accurate when less than 70% of the soil is made up of silt plus very fine sand and less than 4% is made up of organic matter. Select one from the following list:

1 - ENTER K DIRECTLY
2 - ESTIMATE K FROM SOIL CHARACTERISTICS

? 1

K? .31

LS, the slope length and topographic factor, accounts for the influence of topographic relief on the rate of erosion. For uniform slopes LS is determined from the length of slope, the angle of slope, and the category of slope. For irregular slopes (where the angle of slope changes), LS can be computed by first dividing the slope into equal length segments of constant slope and providing the same set of parameters for each segment. Slope length is defined as the length from the point of origin of overland flow to a point of sediment deposition or a confined channel, whichever is shorter. Therefore, slope length may not always be

the distance from ridge line to channel. Select one from the following list:

1 - UNIFORM SLOPE
2 - IRREGULAR SLOPE

? 1

LENGTH OF SLOPE (FT)? 1750

ANGLE OF SLOPE (RISE/RUN X 100)? 7.5

C, the crop management factor, is the ratio of soil loss from a field with a specified crop management to soil loss from a field with fallow soil. A recommended source for C values is Table 10 of Agriculture Handbook No. 537. This table is reproduced in the user guide for this program.

C? .45

P, the erosion control practice factor, is the ratio of soil loss under specified erosion control practices, to soil loss from soil plowed in straight furrows up and down the slope. For areas which have no erosion control practices or for areas which are not plowed (e.g., bare soil, rangeland, reclaimed land), set P = 1.0.

P? 1.0

To determine total tons of sediment production for the entirety of the basin or sub-basin being assessed, input the area of the basin or sub-basin in acres.

BASIN ACRES? 5.01

RAWHIDE MAIN RESERVOIR

RAINFALL FACTOR =	50.0000
ERODIBILITY FACTOR =	.3100
SLOPE LENGTH AND TOPOGRAPHIC FACTOR =	3.8031
CROP MANAGEMENT FACTOR =	.4500
EROSION CONTROL PRACTICE FACTOR =	1.0000
ACRES IN BASIN OR SUB-BASIN =	5.0100

RATE OF SOIL LOSS = 26.53 TONS/ACRE/YEAR
TOTAL SOIL LOSS = 132.90 TONS/YEAR
CUMMULATIVE SOIL LOSS FOR ALL BASINS ANALYZED = 132.90 TONS/YEAR

```
   1 - COMPUTE A SOIL LOSS ESTIMATE FOR A NEW BASIN OR GROUP OF BASINS
   2 - COMPUTE A SOIL LOSS ESTIMATE TO BE ADDED TO PREVIOUS ESTIMATE
   3 - COMPUTE SEDIMENT YIELD
   4 - END PROGRAM RUN

? 4

ready
*
```

The estimated rate of erosion loss for this problem is 132.90 tons/year. If we assume a unit weight for the material of 100 lbs/ft^3, we can compute the following:

$$132.90 \text{ tons} \times 2000 \text{ lbs/ton} = 265{,}800 \text{ lbs}$$

$$265{,}800 \times 1 \text{ ft}^3/100 \text{ lbs} = 2658 \text{ ft}^3$$

$$2658 \text{ ft}^3 \times 1 \text{ acre ft}/43560 \text{ ft}^3 = .061 \text{ acre ft}$$

The Rawhide Mine Permit Application also gives a value of 0.061 acre ft.

V. References

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5. GREEN AND AMPT INFILTRATION ANALYSIS

I. Introduction

The Green and Ampt (10) model is widely used for modeling infiltration (4). It is a relatively simple, physically based, two-parameter infiltration equation which can be derived from a direct application of Darcy's Law. This program implements a single-layer, homogeneous soil version which can accept a rainfall hyetograph as input.

II. Program Theory

The Green and Ampt model assumes that there is a well defined horizontal boundry or *wetting front* which divides the upper and lower portions of the soil column under consideration. In the upper portion the soil is completely saturated from the rainfall on the surface. Below the wetting front the original characteristic water content is maintained and does not influence the rate of saturation. The resulting process is termed *piston flow* and the hydraulic parameters can be derived by substituting the gradient into the Darcy equation for saturated flow.

The following discussion is taken from Eggert, et al. (8) upon which the program described herein is based.

A Green-Ampt type equation may be written as:

$$\frac{F}{\sigma} - \ln\left(1 + \frac{F}{\sigma}\right) = \frac{Kt}{\sigma}, \qquad [5\text{-}1]$$

in which F is the infiltrated volume, K is the hydraulic conductivity of the soil in the wetted zone, t is the time, and is the potential head parameter defined as:

$$\sigma = (\theta_w - \theta_i)\,\Psi_{avg}, \qquad [5\text{-}2]$$

in θ_w is the moisture content of the soil after wetting, θ_i is the antecedent moisture content, and Ψ_{avg} is the average suction head across the wetting front.

If at any time, t, the infiltrated volume is F(t), then at some later time t + Δt:

$$F(t + \Delta t) = F(t) + \Delta F \qquad [5\text{-}3]$$

in which ΔF is the change in infiltrated volume which occurred during the time increment, Δt. An expression for ΔF is obtained from Equation 5-3:

$$\Delta F = F(t + \Delta t) - F(t) \qquad [5\text{-}4]$$

Li et al. (8) developed the following method of solving for the infiltration rate. Their derivation yields:

$$\frac{\Delta F}{\sigma} - \ln\left[\frac{\sigma + F(t) + \Delta F}{\sigma + F(t)}\right] = \frac{K}{\sigma}\,\Delta t \qquad [5\text{-}5]$$

Equation 5-5 is implicit with respect to ΔF. However, the equation is simplified by expanding the logarithmic term in a power series (8):

$$\ln\left(1 + \frac{\Delta F}{\sigma + F}\right) = \ln 1 + \frac{\dfrac{2\,\Delta F}{\sigma + F}}{2 + \dfrac{\Delta F}{\sigma + F}} + \ldots \qquad [5\text{-}6]$$

Truncating Equation 5-6 after the second term and substituting into Equation 5-5, one obtains:

$$\frac{\Delta F}{\sigma} - 2\left[\frac{\dfrac{\Delta F}{\sigma + F}}{2 + \dfrac{\Delta F}{\sigma + F}}\right] = \frac{K}{\sigma}\,\Delta t \qquad [5\text{-}7]$$

Equation 5-7 is simplified into a quadratic whose solution is (8):

$$\Delta F = -\frac{(2F - K\,\Delta t)^2}{2} + \frac{[(2F - K\,\Delta t)^2 + 8K\,\Delta t(\sigma + F)]^{1/2}}{2} \qquad [5\text{-}8]$$

where ΔF is the change in infiltrated volume during time step t to t + Δt. The average infiltration rate, f_{ave}, is obtained by dividing ΔF by Δt, or:

$$f_{ave} = \frac{\Delta F}{\Delta t}, \qquad [5\text{-}9]$$

and compared to the current rainfall rate as entered by the user in the form of a hyetograph.

Based on the outcome of the comparison, the infiltrated volume is updated for the next time step by the potential calculated value if the rainfall rate, r, is greater than the average potential rainfall rate or by:

$$\Delta F = r \, \Delta t \, , \qquad [5\text{-}10]$$

if $r < f_{ave}$. In the former case, a rainfall excess intensity will exist during that Δt; the excess is given by:

$$e = r - f_{ave} \, .$$

In the later case e = 0. The program continues in this manner until the end of the storm thereby supplying the user with an excess rainfall rate histogram presented in tabular format.

III. Program Operation / Limitations

A number of methods for estimating the parameter values for the Green and Ampt model can be found in the literature. Average parameter values have been published for agricultural soils (15). Other methods applicable to other types soils are described in the references listed herein.

The program is applicable to homogeneous soil situations (i.e., single layer versus multilayer soils) and is limited to 300 rainfall increments in the hyetograph of a given problem. This limit should be more than adequate for all practical purposes but can be changed by adjusting the DIM statements for the appropriate variables in the source code. The program is completely menu-driven and prompts the user for all necessary input. A rainfall hyetograph may be input from a previously generated data file. A plot of time versus infiltration rate can be generated at the option of the user. A list of variables used in the program and comments explaining how the program works can be found in the source code.

IV. Example Problem

A flood control dam is planned for a portion of the Donkey Creek Basin. In order to size the structure properly the magnitude of expected flood events must be estimated. One event of interest is the 2-year, 6-hour storm for which the expected rainfall increments are:

Time (min)	Intensity (in/hr)
30	1.86
60	1.116
90	.558
120	.432
150	.432
180	.312
210	.312
240	.246
270	.246
300	.246
330	.246
360	.186

In order to derive a runoff hydrograph, the excess intensity for each of these hyetograph increments must be estimated. Values of .16 inches for average suction head and .3498 inches/hour for conductivity in the wetted zone are used for input to the Green-Ampt program.

```
*BRN A403/GREEN, R

This program uses the  Green - Ampt infiltration  equation  to compute
incremental and cumulative  excess  rainfall and  infiltration volume.
The program implements the homogeneous soil  version  for  time varying
rainfall as represented by a  hyetograph.  Required  input includes the
average suction head and the conductivity in the wetted zone. The rain-
fall intensity  hyetograph  may  be input  from the keyboard or from a
previously generated data file.

SELECT ONE:

    1 - BEGIN A NEW INFILTRATION ANALYSIS
    2 - END PROGRAM RUN

? 1

TITLE FOR OUTPUT? DONKEY CREEK BASIN

WHAT IS THE AVERAGE SUCTION HEAD (IN)? .16

WHAT IS THE HYDRAULIC CONDUCTIVITY IN WETTED ZONE (IN/HR)? .3498

HOW MANY RAINFALL INCREMENTS ARE IN HYETOGRAPH? 12

DO YOU WISH TO INPUT THE HYETOGRAPH FROM THE KEYBOARD OR FROM
A PREVIOUSLY GENERATED DATA FILE (1 OR 2) ?

    1 - KEYBOARD
    2 - FILE

? 1
```

```
 ENTER TIME (MIN) AND RAINFALL INTENSITY (IN/HR) FOR EACH INCREMENT
  (One increment per line with time & rainfall separated by comma)

  INCREMENT NO.     1 ? 30,1.86
  INCREMENT NO.     2 ? 60,1.116
  INCREMENT NO.     3 ? 90,.558
  INCREMENT NO.     4 ? 120,.432
  INCREMENT NO.     5 ? 150,.432
  INCREMENT NO.     6 ? 180,.312
  INCREMENT NO.     7 ? 210,.312
  INCREMENT NO.     8 ? 240,.246
  INCREMENT NO.     9 ? 270,.246
  INCREMENT NO.    10 ? 300,.246
  INCREMENT NO.    11 ? 330,.246
  INCREMENT NO.    12 ? 360,.186

     DONKEY CREEK BASIN

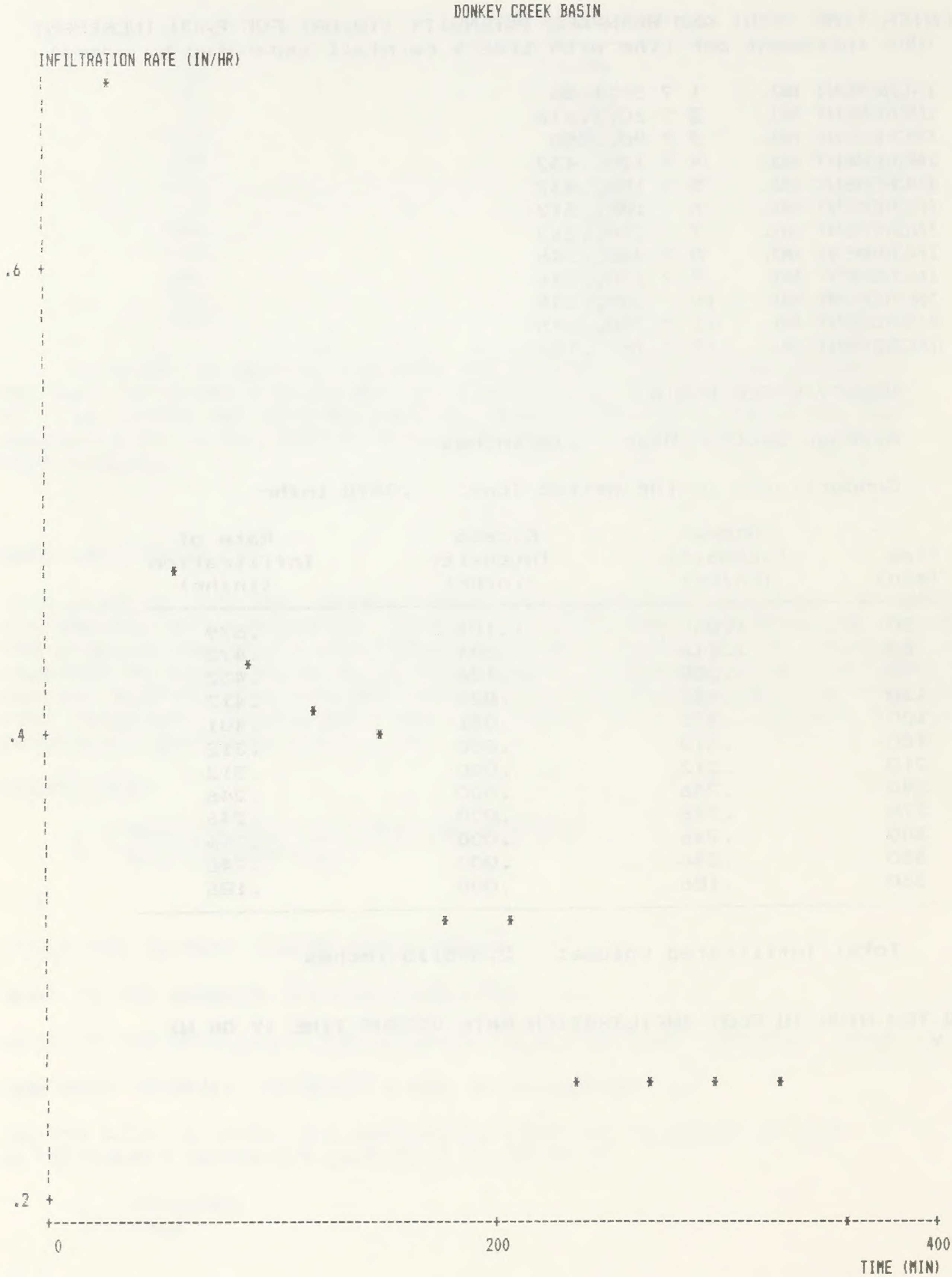
     Average Suction Head:  .16 inches

     Conductivity in the Wetted Zone:   .3498 in/hr
```

Time (min)	Storm Intensity (in/hr)	Excess Intensity (in/hr)	Rate of Infiltration (in/hr)
30	1.860	1.181	.679
60	1.116	.644	.472
90	.558	.126	.432
120	.432	.020	.412
150	.432	.031	.401
180	.312	.000	.312
210	.312	.000	.312
240	.246	.000	.246
270	.246	.000	.246
300	.246	.000	.246
330	.246	.000	.246
360	.186	.000	.186

```
     Total Infiltrated Volume:   2.095115 inches

 DO YOU WISH TO PLOT INFILTRATION RATE VERSUS TIME (Y OR N)
 ? Y
```


DONKEY CREEK BASIN
INFILTRATION RATE (IN/HR)
.6
.4
.2
0
200
400
TIME (MIN)

```
SELECT ONE:

     1 - BEGIN A NEW INFILTRATION ANALYSIS
     2 - END PROGRAM RUN

? 2

ready
*
```

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6. SEDIMENT TRANSPORT ANALYSIS

I. Introduction

This program uses the Meyer-Peter, Muller equation (4) to compute the bedload transport rate for a given sediment size range. The program also computes the suspended sediment transport rate using a numerical integration of an approach developed by Einstein. Program output includes bedload and suspended load for each size range input as well as the total transport rate for all size ranges input (for a given rate of flow). Required input includes the Darcy-Weisbach friction factor, kinematic viscosity, the flow velocity, the width of flow, channel slope, and depth of flow.

II. Program Theory

The following discussion is taken from Eggert, et al. (2) upon which the program described herein is based.

The Meyer-Peter, Muller equation is a simple and commonly used bed load transport equation (6) which has the following form:

$$q_b = \frac{12.85}{\rho \quad Y_B} (T_E - T_C)^{1.5}, \qquad [6\text{-}1]$$

where,

$$T_C = {}_B(\delta_B - \delta)d_B, \text{ and} \qquad [6\text{-}2]$$

$$T_E = \frac{1}{8} \rho f_o V^2. \qquad [6\text{-}3]$$

In equations 6-1, 6-2, and 6-3, q_b is the bed load transport rate in cubic ft per second per ft of stream width, t_c is the critical tractive force, t_E is the boundry shear stress acting on the grain, is the density of water, T_B is the specific weight of the sediment, T is the specific weight of water, d_B is the size of the sediment fraction being analyzed, δ_B is a constant dependent upon flow conditions, f_o is the Darcy Weisbach friction factor, and V is the mean flow velocity obtained by dividing the discharge by the cross sectional area of the flow (Q/A). δ_B is assumed by the program to be 0.047 (2).

The sediment concentration profile which relates the sediment concentration with depth above the bed (3) can be written as:

$$\frac{C_\xi}{C_A} = \left[\frac{R-\xi}{\xi} \quad \frac{a'}{R-a'} \right]^{w}, \qquad [6\text{-}4]$$

in which C is the sediment concentration at a distance a' from the bed, C_A is the known concentration at a distance a' above the bed, and W is a parameter defined as:

$$W = \frac{V_s}{kU_*} \qquad [6\text{-}5]$$

In Equation 6-5, V_s is the settling velocity of the sediment particles, k is the Karman constant (assumed 0.4), and U_* is the shear velocity of the flow defined as:

$$U_* = \left[\frac{T_*}{\rho}\right]^{1/2} \qquad [6\text{-}6]$$

Note that,

$$T_* = \frac{1}{8} f \rho V^2 \qquad [6\text{-}7]$$

where f is the overall Darcy-Weisbach resistance factor.

A logarithmic velocity profile is commonly adopted to describe velocity distribution in turbulent flows. A useful equation is:

$$\frac{u_\xi}{U_*} = B + 2.5 \ln\left[\frac{\xi}{\eta_s}\right] \qquad [6\text{-}8]$$

in which u_ξ is the point mean velocity at the distance from the bed, B is a constant dependent on roughness, and s is the roughness height.

The integral of suspended load above the a' level in the flow is obtained by combining Equations 6-4 and 6-8:

$$q_s = \int_{a'}^{R} u_\xi C_\xi d\xi =$$

$$C_A U_* \int_{a'}^{R} \left[B + 2.5 \ln\left(\frac{\xi}{\eta_s}\right)\right] \left[\frac{R-\xi}{\xi} \quad \frac{a'}{R-a'}\right]^w d\xi . \qquad [6\text{-}9]$$

Let

$$\alpha = \frac{\xi}{R} \qquad [6\text{-}10]$$

and

$$G = \frac{a'}{R}. \qquad [6\text{-}11]$$

The equation becomes,

$$q_B = C_A U_* \int_{a'}^{R} \left[B + 2.5 \ln \left(\frac{\xi}{\eta_B} \right) \right] \left[\frac{1-\xi}{\xi} \quad G - 1 \right]^{\omega} d\xi \, . [6\text{-}12]$$

According to Einstein (3), the concentration near the "bed layer" C_A is related to the bed load transport rate q_b by the expression:

$$q_b = 11.6 \, C_A U_* a' \qquad [6\text{-}13]$$

in which a' is defined as the thickness of the bed layer which is twice the size of the sediment, or $2d_B$.

The average flow velocity V is defined by the equation

$$V = \frac{\int_0^R u_\xi \, d\xi}{\int_0^R d\xi} \qquad [6\text{-}14]$$

Using Equation 6-8 yields,

$$\frac{V}{U_*} = B + 2.5 \ln \left(\frac{R}{\eta_B} \right) - 2.5 \qquad [6\text{-}15]$$

Einstein (1), defined the two integrals in Equation 6-12 as,

$$I_1 = \int_G^1 \left(\frac{1-\alpha}{\alpha} \right)^{\omega} d\alpha \qquad [6\text{-}16]$$

and,

$$I_2 = \int_G^1 \left(\frac{1-\alpha}{\alpha} \right)^{\omega} \ln\alpha \, d\alpha \qquad [6\text{-}17]$$

The integrals I_1 and I_2 cannot be integrated in closed form for most values of W so a numerical integration is necessary. A efficient numerical method of determining I_1 and I_2 was developed by Li (2).

The substitution of Equations 6-13, 6-14, 6-15, 6-16, and 6-17 into Equation 6-12 yields:

$$q_s = \frac{q_b}{11.6} \frac{G^{w-1}}{\left(1-G\right)^{w}} \left[\left(\frac{V}{U_*} + 2.5 \right) I_1 + 2.5\, I_2 \right]. \qquad [6\text{-}18]$$

The total load per unit width of the channel is:

$$q_T = q_b + q_s. \qquad [6\text{-}19]$$

III. Program Operations / Limitations

Applied to stable water courses the Meyer-Peter, Muller formula gives satisfactory estimates of sediment transport. But when the slope becomes larger than 0.00 there may be large differences between computed and observed values. The precision of this formula is also influenced by the size of the bed material. It gives satisfactory results for fine and medium sand bed channels. However, significant discrpancies may occur when estimating sediment discharge in coarse bed material channels (5).

The program allows as many sediment size ranges as desired to be run for any given analysis. It completly menu driven and prompts the user for all necessary input. Output is in a tabular format. A complete listing of the variables used in the program as well as comments describing its operation can be found in the source code.

IV. Example Problem

Due to the presence of a large surface mine, the main channel of Rawhide Creek is to be temporarily routed through a diversion excavated in a silty-sandy aeolian deposit. It is desired to estimate the bedload transport rate of this material at the expected mean flow in order to help determine the stability of the channel.

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This program uses the Meyer-Peter, Muller equation to compute the bedload transport rate for a given sediment size range. The program also computes the suspended sediment transport rate using a numerical integration of an approach developed by Einstein. Program output includes bedload and suspended load for each size range input as well as the total transport rate for all size ranges input (for a given rate of flow). Required input includes the Darcy-Weisbach friction factor, kinematic viscosity, the flow velocity, the width of flow,

channel slope, and depth of flow.

```
SELECT THE PROCEDURE DESIRED:

   1 - SEDIMENT TRANSPORT ANALYSIS
   2 - END PROGRAM RUN

? 1

TITLE FOR OUTPUT ? RAWHIDE CREEK BASIN

DARCY-WEISBACH FRICTION FACTOR ? .025

KINEMATIC VISCOSITY (sq ft/sec) ? .0000111

STREAM WIDTH (ft) ? 8

VELOCITY (ft/sec) ? 2.89

SLOPE (rise/run) ? .0017

HYDRAULIC DEPTH (ft) ? .51

HOW MANY SIZE RANGES DO YOU WISH TO EVALUATE ? 1

GEOMETRIC MEAN PARTICLE SIZE (ft) FOR SIZE RANGE NO.  1 ? .000623

PROBABILITY FOR SIZE RANGE NO.  1 ? 1

RAWHIDE CREEK BASIN

Flow Velocity           =  2.89 ft/sec
Top Width               =     8 ft
Flow Depth              =   .51 ft
Slope                   =    .0017 ft/ft
Darcy-Weisbach Factor   =  .025
Kinematic Viscosity     =  1.11000e-05    sq ft/sec


 SIZE (ft)   PROB   (cfs) -- BEDLOAD -- (lb/sec)   (cfs) -- SUSPENDED -- (lb/sec)
 =========  ======  ============================   ==============================
  .000623    1.00     .00463          .76596        .01857          3.07063

                    ----------      ----------     ----------       ----------
    TOTALS >          .00463          .76596        .01857          3.07063

SELECT THE PROCEDURE DESIRED:

   1 - SEDIMENT TRANSPORT ANALYSIS
   2 - END PROGRAM

? 2

ready
*
```

V. References

1. Chow, V.T., 1964. Handbook of Applied Hydrology, Section 17-II. McGraw - Hill Book Co., New York, NY.

2. Eggert, K.G, Li, R., and Simons, D.B., 1979. Small Calculator Programs for Analysis of Watersheds and River Systems. Colorado State University Research Institute, Fort Collins, Colorado.

3. Einstein, H.A., 1950. The Bed - Load Function for Sediment Transportation in Open Channel Flows. U.S. Dept. Agr., Soil Conservation Service, T.B. No. 1026.

4. Meyer-Peter, E., and Muller, R., 1948. Formulas for Bed-Load Transport. The Second Meeting of the International Association for Hydraulic Structures Research, Appendix 2, pp. 39-64.

5. Simons, D.B., and Senturk, F., 1977. Sediment Transport Technology. Water Resources Publications, Fort Collins, CO.

6. U.S. Bureau of Reclamation, 1960. Investigation of Meyer-Peter, Muller Bedload Formulas. Sedimentation Section, Hydrology Branch, Division of Project Investigations.

7. DETENTION POND ANALYSIS

I. Introduction

Urbanization of a watershed increases the percent of impermeable surface and changes drainage patterns resulting in increases in runoff volumes and peak discharge rates. One method for counter-acting this effect is to construct detention ponds within the basin to limit peak flow rates from developed areas to those which occurred prior to development (1). This program follows the method described in SCS Technical Release No. 55 entitled, *Urban Hydrology for Small Watersheds* (2) for estimating the volume of required detention storage necessary to achieve this goal.

II. Program Theory

TR-55 provides two methods for determining required detention pond storage. The first method, the inflow-outflow-storage method, is recommended when the desired outflow rate from the pond is less than 150 csm (cfs per square mile of drainage area) for a weir-type discharge structure and less than 300 csm for a pipe discharge. The second method, the volume-rate method, is recommended for outflow rates above these maximums. The later method is implemented in this program.

The volume-rate method utilizes a curve which relates the ratio of the volume of storage and volume of runoff (V_S/V_R) to the ratio of peak rate of outflow to peak rate of inflow (Q_O/Q_I). The curve was developed using known relationships involving a Type II storm distribution applied to a 24-hour rainfall and assumes that the volume available for temporary storage is small relative to the expected runoff volume.

Normally, to apply the volume-rate method to derive a required storage volume, the user must estimate the runoff volume and peak discharge rate under post development conditions for a given 24-hour storm. Using the ratio of Q_O (the rate of peak discharge desired from the pond after development) to Q_I (estimated post-development rate of inflow) the ratio of required volume of storage to estimated post-development runoff volume can be derived from the volume-rate curve. Since:

$$\frac{V_S}{V_O} = \text{ratio} \qquad [7\text{-}1]$$

then, $V_S = V_O$ (ratio). [7-2]

In order to avoid the need to use the volume-rate curve, the program uses the following polynomial approximation:

$$\frac{V_S}{V_O} = \left[1 - 2 \frac{Q_O}{Q_I} + 1.8 \left(\frac{Q_O}{Q_I} \right)^2 - 0.8 \left(\frac{QO}{Q_I} \right)^3 \right] \qquad [7\text{-}3]$$

The program also provides the option to compute the estimated volume of runoff using the SCS curve number method. The volume of runoff depends upon the volume of precipitation and the volume retention due to infiltration, surface storage, and other factors. Retention is defined as the difference between the volume of precipitation and the volume of runoff. The SCS method assumes that a certain volume of precipitation at the beginning of the storm, called the initial abstraction, will not appear as runoff. These relationships are inherent in the following equation:

$$\frac{F}{S} = \frac{Q}{P - I_A} \qquad [7\text{-}4]$$

where,

- F = actual retention,
- S = potential maximum retention,
- Q = volume of runoff,
- P = volume of precipitation, and
- I_A = initial abstraction.

The actual retention is therefore:

$$F = (P - I_A) - Q. \qquad [7\text{-}5]$$

Substituting Equation 7-4 into Equation 7-5 yields:

$$\frac{(P - I_A) - Q}{S} = \frac{Q}{P - I_A}, \qquad [7\text{-}6]$$

and solving for Q yields,

$$Q = \frac{(P - I_A)^2}{(P - I_A) + S} \qquad [7\text{-}7]$$

Empirical data suggests that:

$$I_A = 0.2S, \qquad [7\text{-}8]$$

and substituting Equation 7-8 into 7-7 yields,

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} . \qquad [7-9]$$

Empirical data indicates that:

$$S = \frac{1000}{CN} - 10, \qquad [7-10]$$

where CN = runoff curve number for the basin under study and is a an index of soil type, land use, agricultural land treatment class, hydrologic condition, and antecedent moisture condition. Methods for choosing CN values are discussed in a number of widely distributed publications including, *The SCS National Engineering Handbook, Section 4, Hydrology* (3), and *Design of Small Dams*(2).

III. Program Operation / Limitations

TR-55 states that in instances where runoff curve numbers are less than 65 in combination with short times of concentration, V_s/V_r will be up to 25 percent too high. Runoff curve numbers over 85 with long times of concentration cause V_s/V_r values to be up to 25 percent too low. For weir flow structures with desired outflow rates less than 150 csm or pipe flow structures with desired outflow rates of less than 300 csm, the graphical inflow-outflow-storage method in TR-55 should be used.

The program accepts a design storm rainfall amount in inches which is then converted to a volume by applying the watershed drainage area. Runoff amounts which are input directly in inches are converted in the same manner. As the following example illustrates, a required detention pond storage volume can be computed by entering the desired outflow rate, or the resulting outflow rate can be computed given an available storage volume. The program is completely menu-driven and prompts the user for all input. A list of the variables used in the program and comments describing its operation can be found in the source code.

IV. Example Problem

A new housing development has just been completed in the Donkey Creek basin. Is desired that a storm runoff retention pond be constructed to maintain downstream flows at the same rate as pre-development. Prior to development the basin curve number was estimated at 60. After development the curve number has increased to 80. The drainage area above the proposed detention pond is 30 acres. The pond is to be designed for the 10-year, 24-hour storm for which the precipitation amount is 4 inches. Post development is to be kept to 9 cfs and the design storm inflow rate is estimated at 38 cfs. What size pond is required ? If 2.3 acre-ft

is available for the pond, what can the expected outflow be reduced to ?

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This program calculates the pond volume required to detain the excess runoff occuring because of a change in basin runoff conditions. Detention pond volume is calculated using estimated peak inflow, desired peak outflow, and the expected excess runoff volume. Excess runoff volume can either be input directly (pre- and post rainfall excess) or can be calculated using SCS methods (pre- and post Curve Numbers). The program will also calculate expected peak outflow from a detention pond given rainfall excess, storage capacity, and peak inflow. To begin the program select one of the following options:

```
          1 - COMPUTE POND DETENTION VOLUME
          2 - COMPUTE EXPECTED PEAK POND OUTFLOW
          3 - END PROGRAM RUN

? 1

TITLE FOR OUTPUT? DONKEY CREEK POND

INDICATE HOW YOU WISH TO INPUTE RAINFALL EXCESSES:

      1 - ENTER RAINFALL EXCESSES DIRECTLY
      2 - CALCULATE EXCESSES FROM SCS CURVE NUMBERS

? 2

ENTER CURVE NUMBER PREVIOUS TO CHANGE IN WATERSHED:
? 60
ENTER CURVE NUMBER AFTER CHANGE IN WATERSHED:
? 80
ENTER 24-HOUR RAINFALL FOR DESIRED DESIGN STORM (IN):
? 4

WATERSHED DRAINAGE AREA (ACRES)? 30

ESTIMATED POND PEAK INFLOW RATE (CFS)? 38

DESIRED POND PEAK OUTFLOW RATE (CFS)? 9

DONKEY CREEK POND

INCREASED RAINFALL EXCESS =      1.2798 IN
DRAINAGE AREA =                 30.0000 ACRES
ESTIMATED PEAK INFLOW =         38.0000 CFS
DESIRED PEAK OUTFLOW =           9.0000 CFS

POND STORAGE REQUIRED =          1.9729 ACRE-FT
```

```
            1 - COMPUTE POND DETENTION VOLUME
            2 - COMPUTE EXPECTED PEAK POND OUTFLOW
            3 - END PROGRAM RUN

? 2

TITLE FOR OUTPUT? DONKEY CREEK POND

INDICATE HOW YOU WISH TO INPUTE RAINFALL EXCESSES:

       1 - ENTER RAINFALL EXCESSES DIRECTLY
       2 - CALCULATE EXCESSES FROM SCS CURVE NUMBERS

? 2

ENTER CURVE NUMBER PREVIOUS TO CHANGE IN WATERSHED:
? 60
ENTER CURVE NUMBER AFTER CHANGE IN WATERSHED:
? 80
ENTER 24-HOUR RAINFALL FOR DESIRED DESIGN STORM (IN):
? 4

WATERSHED DRAINAGE AREA (ACRES)? 30

AVAILABLE POND STORAGE (ACRE-FT)? 2.3

EXPECTED INFLOW (CFS)? 38

DONKEY CREEK POND

INCREASED RAINFALL EXCESS =     1.2798 IN
DRAINAGE AREA =                30.0000 ACRES
ESTIMATED PEAK INFLOW =        38.0000 CFS
POND STORAGE AVAILABLE =        2.3000 ACRE-FT

ESTIMATED PEAK OUTFLOW =        6.4320 CFS

            1 - COMPUTE POND DETENTION VOLUME
            2 - COMPUTE EXPECTED PEAK POND OUTFLOW
            3 - END PROGRAM RUN

? 3


ready
*
```

V. References

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2. U.S. Bureau of Reclamation, 1977. Design of Small Dams. U.S. Government Printing Office, Washington, D.C.

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4. U.S. Soil Conservation Service, 1975. TR-55: Urban Hydrology for Small Watersheds. Technical Release No. 55, U.S. Gov. Printing Office, Washington, D.C.